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Education Department Bulletin

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New York State Museum

John M. Clarke, Director

Museum bulletin 127

GLACIAL WATERS IN CENTRAL NEW YORK

BY

H. L. FAIRCHILD

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Hon. Andrew S. Draper LL.D.
Commissioner of Education

SIR: I communicate herewith for publication as a bulletin of the State Museum a paper prepared at my request by Prof. H. L. Fairchild on the *Glacial Waters in Central New York.*

Very respectfully yours
JOHN M. CLARKE
Director

State of New York
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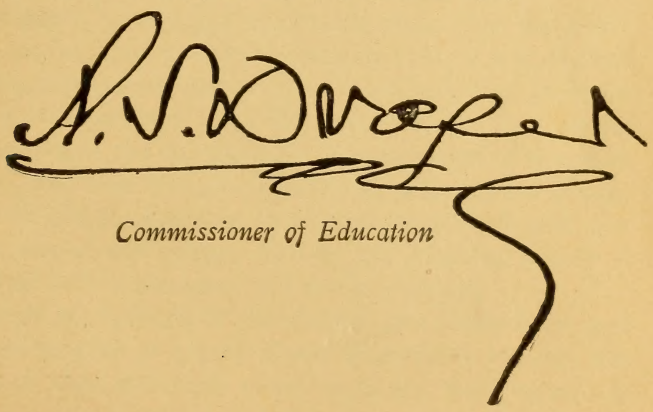
Approved for publication this 20th day of November 1907



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Museum bulletin 127

GLACIAL WATERS IN CENTRAL NEW YORK

BY

H. L. FAIRCHILD

INTRODUCTION

Scope of the paper. Several of the earlier papers by the writer described the glacial lakes or standing waters held in central New York by the waning glacier [*see* the bibliographic list, p. 59, titles 16, 25, 26]. Later writings have for their subject the glacial drainage channels and the ice-impounded waters east of Syracuse [titles 27, 28, 31] and west of Batavia [title 37]. The present writing describes the ice border drainage in central New York and discusses the relation of this stream flow to the standing waters of the region and to both the eastern and western escape.

While the drainage features of the district are conspicuous and their origin by the work of glacial rivers is perfectly evident yet their sequence in time and their relations to the lake waters are not clear without careful study of the entire region. The glacial lake history in central New York is somewhat more complicated than has been supposed, and the drainage phenomena are involved in the problems.

Maps. The key map, plate 1, shows the channels in a generalized way from the neighborhood of Batavia east to Utica and Little Falls, thus covering all the territory on the east described in former writings. The key map published in the State Museum bulletin

[title 37] shows the west-leading channels west of the Batavia district. These two general maps depict all the glacial stream channels in central-western New York except those leading to southern drainage and the higher cross-ridge channels.

The detailed maps, plates 2–5, utilize as a base the sheets of the New York State topographic map. The series herewith given forms a complete map of the belt along the 43d parallel between Leroy and Oneida, a distance of over 125 miles, with the exception of the Weedsport quadrangle, on which no channels have been located.

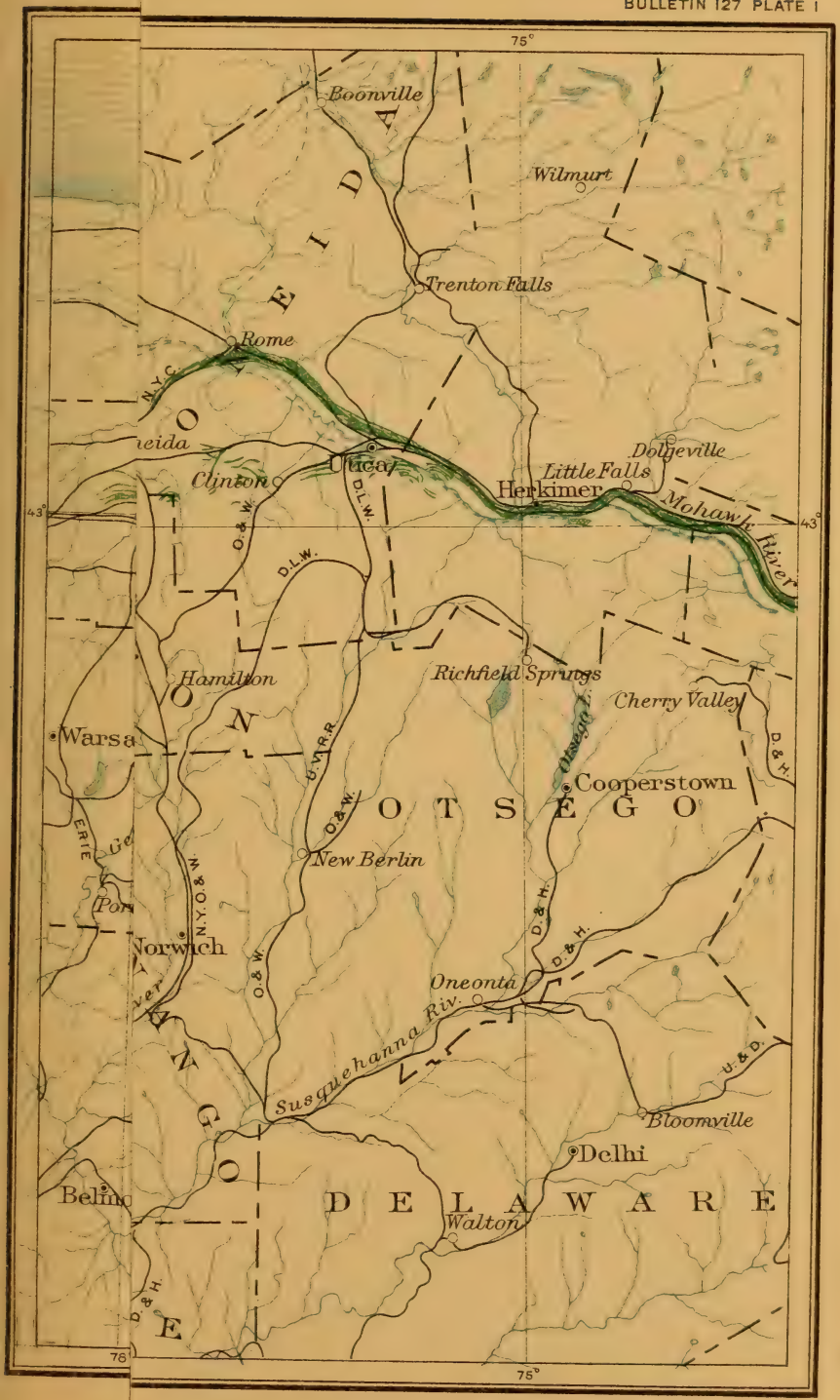
Beyond the territory of plate 5 the glacial stream channels have already been depicted in the same style or convention employed in the accompanying maps. The maps included in former publications [titles 28, 31, 37], in conjunction with the maps here in hand show with some detail all the later ice border drainage from the extreme west end of the State, at State Line, eastward to Little Falls in the Mohawk valley.

Acknowledgments. For courtesies and assistance in the study of the glacial geology of central New York the writer is under pleasant obligations to many persons, and special thanks are due the following: Dr C. E. Fairman, Lyndonville; Mr J. W. Holmes, Batavia; Mr W. S. Hosmer, Clifton; Mr E. P. Clapp, North Rush; Mr J. P. Slocum, Albany, formerly of Nunda; Mr Shelley G. Crump, Pittsford; Mr D. D. Luther, Naples; Mr N. L. Ogden, Penn Yan; Dr M. A. Veeder, Lyons; Mr Philip F. Schneider, Syracuse; Dr S. Ellis Crane, Onondaga Valley and Prof. George H. Chadwick, Canton.

Dr G. K. Gilbert was the first to recognize the significance of the drainage features, and to him the writer is especially indebted.

Terminology. A few words require frequent repetition in this writing. To save a reiteration of the term "channel" as applied to the excavated path of a stream, the term "scourway" will sometimes be used to name the shallow and less definite channels. "Gorge" and "canyon" will sometimes be applied to deep, narrow channels, specially if they have rock walls. The common terms cut, notch and terrace will sometimes be used where appropriate.

The terms "ice border" and "proglacial," applied to the drainage along the edge or front of the ice sheet, are used as equivalents.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N.Y.C.
Clinton
Utica
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Dolgeville
Mohawk River
43°
O.&W.
D.L.W.
Hamilton
Richfield Springs
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KEY MAP OF DISTRICT BETWEEN LEROY and LITTLE FALLS SHOWING THE CHANNELS OF ICE BORDER DRAINAGE

H. L. FAIRCHILD
1906

GENERAL DESCRIPTION: PRELIMINARY OUTLINE

The glacier acting as a barrier to northward drainage is the fundamental fact to be apprehended by the reader. The ice sheet was a melting dam during both its advance and its retreat, and waters were flowing copiously from it, not into it. Valleys or land depressions sloping toward the ice front were by the ice barrier made into lake basins [*see* pl. 34–42].

The earliest outlets for the ice-dammed waters were at the heads of the greater valleys, or across the cols, to southern drainage. A later escape of the waters was by flow past the ice margin across the ridges between the lakes, thus draining higher valley lakes into lower lakes. These cross-ridge outlets were successively lowered and shifted northward as the ice front receded, until at lower levels the proglacial drainage formed extended rivers on the intervalley stretches. Rivers of glacial water had no less power of carving channels and building deltas than other streams, and these effects of the ancient rivers are still conspicuous evidence of their existence.

West of Batavia all the glacial waters escaped westward to the lakes held in the Erie basin [*see* title 37, p. 10] and ultimately to the Mississippi river. The same is true of all the waters held in the Genesee region under about 1200 feet (the lowest southward escape of Genesee waters; *see* title 40). This is probably true, also, of all the glacial waters of central New York between the Newberry plane (about 1000 feet on the Batavia parallel) and 900 feet, the elevation of the lowest west-leading channels at Batavia. All the drainage under 900 feet was eastward past Syracuse to the Mohawk valley. These east-leading channels, from their heading near Leroy to beyond Syracuse, form the subject of the present writing.

The general history may be clearer if the physiography of the region is emphasized. In the territory between the meridians of Batavia and Syracuse, covered by the accompanying maps and plates 1–5, at least 13 distinct valleys lie sloping northward. Named in order from west to east these are Oatka, Genesee, Conesus, Honeoye, Bristol (Mud creek), Canandaigua, Flint, Seneca, Cayuga, Owasco, Skaneateles, Otisco and Onondaga. The higher and more local glacial waters in these valleys had different outflow seeking southward escape, but a later stage saw the waters of the broad area collected mainly into two large lakes. One of these was Lake New-

berry which occupied the large, low, central valleys of Seneca, Cayuga and Keuka, with its outlet south through the village of Horseheads to the Chemung-Susquehanna, at a present altitude of 900 feet [*see* titles 16, 26]. The other was the Genesee valley waters which escaped at different times and levels to Susquehanna, Allegany-Ohio-Mississippi and Erian-Mississippi drainage [*see* title 40].

The latest stage of the waters, previous to the initiation of the channels to be described, seems to have been the union of these two bodies of water into one extensive lake, outflowing westward by the lowest channels southwest of Batavia, above 900 feet, into Lake Warren. Whether Lake Newberry found any escape eastward, in the vicinity of Syracuse, before its lowering waters became confluent with the Genesee waters is not certain, but this seems unlikely. This wide extended central New York water probably extended from Batavia eastward nearly to Syracuse; bounded on the north by the ice front, and with many southward prolongations extending up the valleys. It is the same water as noted above lying in altitude between the Newberry plane and 900 feet, and is an important lake in relation to the drainage history of the region. It is the lowest stage of the waters formerly called the Warren Tributary lake, the seventh stage of the Genesee glacial waters as described in a former writing [title 21]. These waters were falling in altitude, indefinite in boundaries and comparatively transitory in life, on which account they might not deserve a distinctive name; but being an important link in the chain of lake succession, and requiring frequent mention, it is desirable to give them a name, and we have called them Lake Hall, after James Hall, whose classical report [title 5] covered the outlet district [*see* title 40 and pl. 36].

While the ice-fronting waters were standing at the Batavia level it appears that the waning of the ice barrier in the Split Rock district, west of Syracuse, opened outlets for the water lower than the Batavia escape and the flow was diverted to the east. The continued eastward flow at falling levels produced the stream phenomena which form one special subject of this writing. The facts of observation on which the above history is based will be given below in the descriptive matter. As a distinctive name we have called these standing waters with falling levels and eastward escape Lake Vanuxem, after Lardner Vanuxem, whose territory in the first New York survey [title 4] included the Syracuse region [*see* pl. 37].

One important change in the conception of the glacial lake his-

tory must be noted here. In former writings it was supposed that immediately subsequent to the Batavia outflow the Warren waters invaded the region, from the west, and that the falling Warren, or hypo-Warren waters carved the channels under discussion. In this view the Leroy-Syracuse channels were the latest or closing phenomena of the glacial waters in the region. On the contrary it now appears, with the larger range of facts available, that these channels antedated the Warren waters. The Warren planes, 880 feet, and Dana (hypo-Warren) phenomena, 700 feet, are found far northward of the channels [*see* pl. 2, 3]. The channels were certainly formed at the receding ice border Equally certain it is that the Warren phenomena north of Victor and Fishers, and the Dana cliffs and spits near Bergen and Elba have never been touched by an ice sheet. The only possible conclusion seems to be that the Warren invasion occurred after the low channels were cut at Leroy, Rush, Victor, Clifton Springs, Phelps and the Split Rock district. The very pronounced channel farther north, extending from Fairport to Lyons and eastward, and correlating with the low passages at Weedsport, Jordan, Memphis and Syracuse may have been post-Warren.

The present conception of the lake history negatives the idea of a steady, continuous, single recession of the ice front in central-western New York and requires instead some oscillation of the ice front and a seesawing as between the meridians of Batavia and Syracuse. The low channels through the city of Syracuse must have been open in order to allow the river flow through Victor-Phelps at 500 feet; and the Warren waters were then excluded by the ice barrier lying against the high ground north of Batavia. On the other hand the existence of Lake Warren in central New York, the proofs of which are positive, requires a recession of the ice north of Batavia and the readvance and blocking of the Syracuse channels up to at least 890 feet.

On the Split Rock meridian there is a singular complication of the channel phenomena, described on page 23, which also requires oscillation of the ice barrier on that line.

To return to the general description of the channel features: On any meridian the channels lie in series, falling northward, as required on the theory of a receding barrier. This feature may be clearly seen on the meridians of Mumford and Rush, plate 2; Shortsville and Clifton Springs, plate 3; and very strikingly at Split Rock and Jamesville, plate 4. This fact is sufficient proof that these

channels were carved directly at the ice edge, or in other words that the streams here laved the ice front. On the other hand the Fairport-Lyons channel although initiated at the ice front continued to remain effective long after the ice had left that parallel, for the reason that higher ground lies on the north.

The higher (southward) and more interrupted channels lie on the steeper part of the north-facing slope, formed by the scarp of the Onondaga limestone, and are frequently only benches in the slope. That is to say, only the south banks of the channels are in existence, as the north bank was the glacier ice. The lower and more continuous channels are in the soft Salina shales; those at Mumford, Scottsville, Rush and Mendon [pl. 2] and Victor [pl. 3] being in the upper and harder shales, while the channels east of the Cayuga meridian are in the very soft and erodible lower (Vernon) shales.

The maps will show that the stream flow was interrupted by north and south depressions, and it will be understood that these surfaces below the channels must have been occupied by standing waters or lakes. Into these lakes the inflowing streams carried their burdens of detritus and built deltas in the western margins of the lakes. A necessity for the continuous flow was a sequence of declining channels to the eastward.

Two pronounced depressions lie athwart the general course of the stream flow. One is the Genesee valley, some 3 to 4 miles wide, in the waters of which the rivers from the west built broad deltas, extending north from Fowlerville to Scottsville. The other depression is the Cayuga basin, the broad tract of the Montezuma marshes. Over this stretch of about 25 miles, or between the meridians of Geneva and Jordan the waters seem to have formed an extensive but shallow lake.

The eastern channels, in the Syracuse district and eastward, are more broken by deep, narrow valleys. The plateau of southern New York, trenched by preglacial stream valleys, reaches to the Syracuse parallel where it drops off abruptly. At different times and for many centuries the glacier front rested against the steep north edge of the plateau all the way from the Skaneateles meridian east to Utica, and the escaping waters were forced to cut deep trenches or notches in the north ends of the intervalley ridges. The valleys in which waters were ponded with changing levels are: Skaneateles, Otisco (Marcellus), Onondaga, Butternut and Limestone, and several valleys farther east; all of which have been described, in this relation, in former papers [*see* titles 25, 26, 28, 31].

CHANNEL OF ICE-BORDER DRAINAGE

"The Gulf," 3 miles west of Mumford. View looking northeast (downstream)

The chronologic order of the glacial stream flow seems to have been as follows, at least in its general sequence. The eastern channels were opened successively to the westward, that is from Little Falls and Utica westward to Syracuse, thus permitting eastward flow to the Mohawk valley. During the same time the waters in the Erie basin were invading eastward thus allowing westward flow toward the Mississippi [*see* titles 31, 37]. The waning of the ice front on the west finally permitted westward flow at Batavia as low as 900 feet (Lake Hall), while the ice barrier at Syracuse was yet higher. Later the ice front at Syracuse gave way and all the waters lying east of Batavia and under 900 feet (Lake Vanuxem) were drained eastward to the Mohawk, and the channels emphasized in this writing were then cut. Subsequently a readvance of the glacier in the vicinity of Syracuse and a recession north of Batavia let the Erian waters (Lake Warren) into central New York. Finally another and last recession of the ice at Syracuse permitted low eastward flow and the Warren and hypo-Warren waters were lowered to Lake Iroquois.

The above is only an outline of the main events in the history and is probably inadequate. At least this sequence of ice recession and readvance seem requisite in order to explain the facts as known at present, but it is possible that the oscillations of the ice front in New York were greater in number and the whole history more complicated than is here outlined, and that important events occurred which are not yet even suspected. Some of the puzzling features which suggest complications will be noted later, specially in description of the phenomena in the Split Rock and Syracuse districts.

DETAILED DESCRIPTION

Batavia to Genesee valley

The earliest and highest of this series of ice border drainage channels heads northeast of Leroy on the Onondaga (Corniferous) limestone, at 800 feet altitude. The map, plate 2, shows the stronger or more definite scourways. The later and lower channels head in faint scourways 4 to 6 miles northwest of Leroy, beginning in drift but soon cutting down through the thin edge of the limestone into the underlying Salina shales [pl. 6].

The higher channels east of Leroy swing southeast, up the Genesee valley, while the later channels keep an eastward course. This change in direction of the channels indicates that a lobation

of the ice front rested in the Genesee depression east of Leroy when the earliest ice border drainage occurred, but that the lobation had disappeared when the later channels, leading east toward Scottsville, were made.

All these glacial channels end in the Genesee valley at about 600 feet altitude where they built a series of broad deltas, extending from Fowlerville north to Scottsville through a distance of 12 miles [pl. 7–9]. The control of the water level in the valley was exercised by the channels which carried the lake waters out of the valley and which will be described in the next chapter.

Four lines of railway traverse the channel district from east to west, taking advantage of the level stretches on the limestone prepared by the ancient rivers. All these features are fairly shown on the map, but a few special features require verbal description.

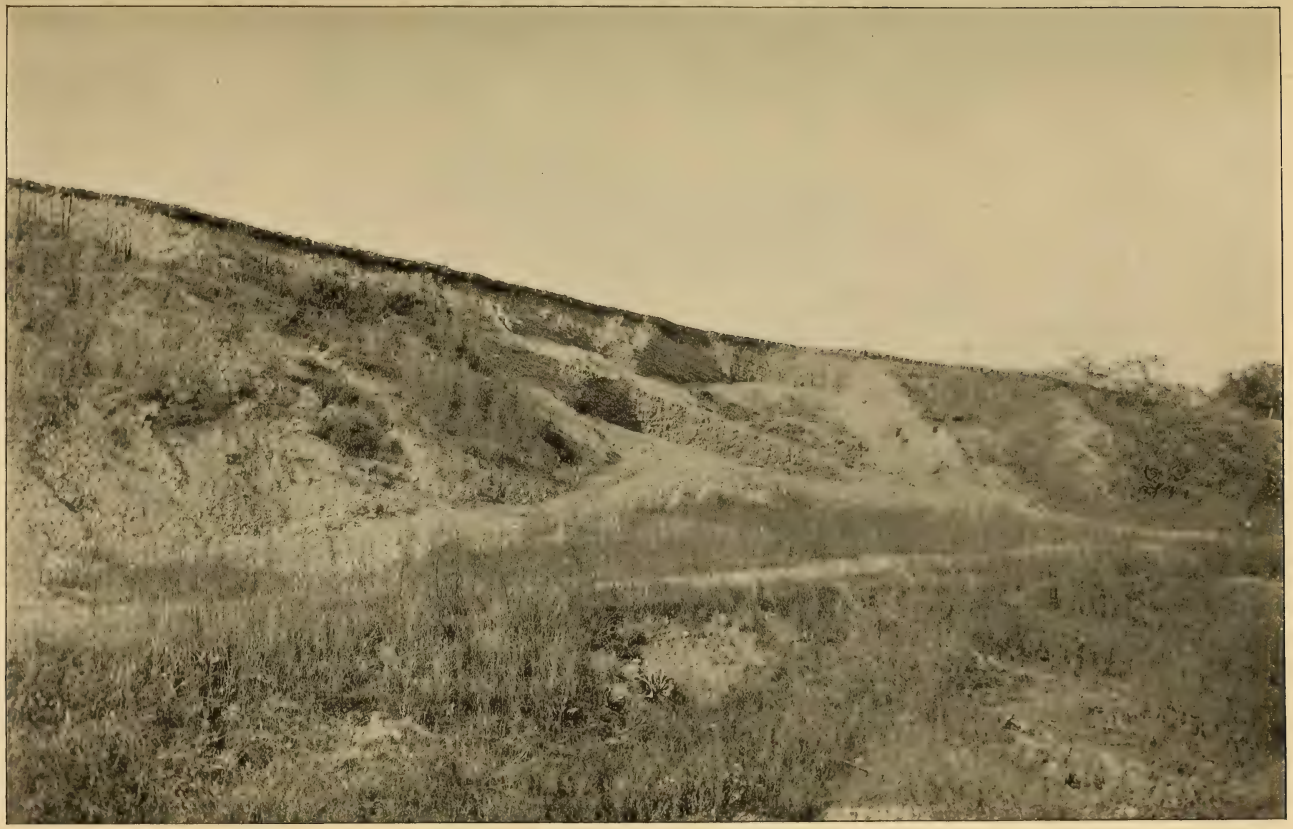
The morainal or marginal drift of the ice sheet is too scanty to represent on the map. There are two reasons for this; first, that the rock rubbish carried by the ice was largely gathered into the drumlin masses, as shown in the upper part of the map, plate 2; second, that the vigorous river work at the retreating ice margin swept the morainal drift eastward into the deltas. Over extensive areas the limestone is practically bare.

The axial directions of the drumlins should be noted. The drumlins south of the parallel of Scottsville have a general north and south attitude, or even northwest by southeast in the vicinity of Linwood, in conformation to the valley slope, produced by the southward flow of the ice lobe in the valley; while the northern drumlins have a northeast by southwest direction, the prevailing direction of all the ice-molded drift on the Ontario plain west of the Genesee valley.

The most singular feature of the district relates to the limestone rock. It will be noted that on the map in the belt traversed by the three east and west railways the channels are not definitely bounded or limited. This is not from lack of knowledge of the district nor because the channels are doubtful. There is no lack of evidence of vigorous stream work, for all the drift has been removed and the limestone eroded. But the rock strata has been so disturbed and the surfaces tilted since the rivers did their work that the continuity of the channels and their walls is largely obscured. The surface of the limestone is thrown into a large number of low but conspicuous ridges and shallow basins due to settling or sinking of the strata. These features were noted in 1891 by G. K. Gilbert and

DELTA OF ICE-BORDER DRAINAGE

West side of Genesee valley, near Canawaugus, 2 miles west of Avon. General view of excavation by the Erie Railroad. Looking east. Compare plates 8 and 9



DELTA OF ICE-BORDER DRAINAGE

West side of Genesee valley. Canawaugus, 2 miles west of Avon. Looking north at front of delta shown in plates 7 and 9

DELTA OF ICE-BORDER DRAINAGE

West side of Genesee valley, near Canawaugus, 2 miles west of Avon. Part of Erie Railroad excavation shown in plates 7 and 8

attributed to the sinkage of the superficial strata by the removal of the underlying salt and gypsum beds through solution [*see* title 8]. South of this parallel, in the Genesee and Oatka valleys are the mines of rock salt and the factories using the brine.

All the ground between Mumford, Caledonia and Leroy is much broken by sinks and sink ridges, of varied dimensions. The ridges vary from doubtful irregularities of the surface up to sharp, broken anticlines sometimes 10 or even 15 feet in hight [*see* pl. 10]. Some of the ridges are short and irregular, many long and winding. Perhaps the more extended are east and west in trend, or along the strike of the rock. The higher and steeper ridges in places resemble scarps due to differential weathering, and some even resemble in form wave-cut cliffs or stream banks. On first inspection the forms would be liable to varied misinterpretations.

These sinkage structures are not only postglacial but subsequent also to the glacial drainage, as they have broken up and obscured the channels. It is suggested that the removal of the soil cover by the glacier, along with some of the superficial, weathered rock, and the subsequent removal of the glacial drift by the ice border rivers exposed the fissures in the strata. The rivers and the subsequent lakes (Warren and Dana) supplied a large volume of water during many centuries for the subterranean circulation and probable removal of a portion of the lower limestone beds and the underlying gypsum.[1] Conspicuous ridges lie along the north side of the highway midway between Caledonia and Leroy for a stretch of 2

[1] Bearing on the origin of the sinkage features the following may be noted.

The surface rocks of the area are Onondaga limestone, beneath which occur in descending order Cobleskill limestone; Bertie waterlime; Camillus (gypsiferous) shales. The gypsum beds lie less than 100 feet below the surface, and are partly above the present surface drainage on the north. Below the base of the Onondaga the depth of the salt is 440 feet at Leroy and 486 feet at Caledonia. The thickness of the salt beneath Leroy is given as 15 feet; and it lies 253 feet above sea level. At Caledonia the highest salt bed is at or below sea level, and south of the parallel the beds are considerably below sea level, due to the southward dip of the strata. Considering that the salt is not only below the level of free circulation but covered by hundreds of feet of quite undisturbed shales the chance for rapid removal seems small. On the other hand the gypsum and the limestones are exposed to subsurface waters with clear drainage. It is important to note that both here and at Syracuse the sinkage has been observed only in the belt along the summit of the Onondaga escarpment.

The parallel of Caledonia and Leroy is the northern edge of the salt-bearing area, the sinkage structures extending a mile or two north of the line. South of the parallel the salt beds increase in thickness, along with the increasing depth below sea level. It has been thought that the present northward limitation of the salt was the original limit of the deposits, but the possible removal of some portion of the northern edge of the beds should be considered.

A point worthy of consideration is the possible amount and the form of the surface dislocation that would be produced by the slow removal of even some scores of feet of salt beneath more than 400 feet of rock, mostly shales. The writer concludes that the irregularity and the sharp relief of the sinkage features indicates the subsidence of only a moderate thickness of rock — perhaps 100 feet.

or 3 miles and are visible from the three railroads. All the ground north of the railroads from Caledonia and Mumford to Leroy has been stream-eroded but the scourways can not be definitely mapped. Similar sinkage features occur on the limestone escarpment west of Syracuse [*see* p. 24].

The altitudes of the channels, always declining eastward, and always successively lower in northward sequence, are sufficiently shown by the topographic contours and numerals of the map. The higher channels, those east of Leroy, carried the overflow of the Oatka valley in addition to the supply from the melting ice, from all the stretch of the glacier front east of Batavia. The lower channels, heading in indefinite scourways northwest of Batavia do not suggest any overflow of the Erian waters eastward past the salience north of Batavia, but seem to have carried only the local waters of the melting glacier and the shallowing lake.

Genesee valley to Irondequoit valley

The glacial drainage described in the preceding chapter built extensive deltas on the west slope of the Genesee valley. This implies lake waters in the valley with correlating outlets on the east. The deltas have altitudes ranging from about 620 feet down to 580 feet, and at precisely these elevations we find capacious channels leading eastward. These are so clearly shown on the map, plate 2, that little verbal description is necessary.

It will be seen that the lowest channel, in which lie the villages of Rush, Rochester Junction and Mendon, is followed by the Lehigh Valley Railroad, and that the Batavia-Canandaigua branch of the New York Central Railroad utilizes for short distances two of the higher channels. The highest cuttings, from 700 feet down, lie west of Honeoye Falls [pl. 11] and are mostly cut terraces or shallow scourways in the Onondaga limestone. The irregular surfaces of the bare rock would not at first sight be confidently attributed to river work, but comparison and correlation study over the district gives certainty.

Southwest of Honeoye Falls, 2¼ miles, is a low cataract and plunge basin known locally as "Dry Pond," produced in the course of the highest channel on the map, at about 680 feet [pl. 12].

Like all the lower channels the Rush-Mendon channel is cut in Salina shale. The highest continuous channel passes a mile north of Honeoye Falls with an altitude of 620 feet. Bending to the northeast it continues around the north side of the Victor kame area,

SINK RIDGE

Broken limestone in anticlinal form produced by subsidence of the adjacent areas. 2 miles west of Caledonia

WORK OF ICE-BORDER DRAINAGE

Bare Onondaga limestone, "Stull farm," 3 miles west of Honeoye Falls. Looking northwest. Compare plates 18, 29 and 30

CATARACT BASIN IN GLACIAL STREAM CHANNEL

"Dry Pond," 2 miles southwest of Honeoye Falls. Looking westward (upstream)

partly as a cut bank, until it blends with the broad Victor channel, described in the next chapter. The lower channel, Rush-Mendon [pl. 13] terminates near Mendon village in a delta, somewhat eroded by recent stream work, lying between Mendon and Fishers, with an altitude of 600 to 580 feet. This delta lies at the present head of the Irondequoit valley, and the glacial waters, which we may call the Fishers lake, had eastward escape through the Victor channel.

One puzzling feature in this district is a coarse, cobbly gravel deposit 1½ miles northwest of Honeoye Falls and east of Sibleyville corners. The Hemlock branch of the Lehigh Valley Railroad has extensively excavated the deposit and revealed a delta structure indicating river flow toward the north or northeast [*see* pl. 14]. This direction is consonant with the preserved glacial channels, but in other respects the deposit does not clearly correlate with the supposed river flow. Modern drainage, specially Honeoye creek, has considerably changed the topography as it was left by the glacial streams, and it is possible that the delta represents an early and higher stream flow at that point. Perhaps it represents work of an earlier ice border drainage during the invasion by the glacier.

Irondequoit valley to the Cayuga depression

Higher series: Victor to Phelps

The glacial drainage across this stretch of 23 miles [*see* pl. 3] although somewhat broken and varied must be studied as a unit. To the continuity of the lower channels there is only one decided interruption, the break at Manchester.

The Lehigh Valley Railroad follows this drainage tract through its whole extent, and the Auburn branch of the New York Central Railroad also, except between Victor and Shortsville.

The highest channel that has been located in this series is quite separated from the others. Plate 3 shows it lying south of Paddleford station and passing east of north to the narrow and poorly defined valley of the Canandaigua outlet, which it intersects less than a mile south of Shortsville. This small but definite channel declines from 740 down to 620 feet. East of the modern Canandaigua outlet and southeast and east of Shortsville there are several scourways and stream banks, from near 700 feet down to 620 feet, which carried the eastward escape of the Canandaigua valley waters, the flow passing immediately south of Clifton Springs.

All the northern edge of the Onondaga limestone in the stretch

of 9 miles between Shortsville and Phelps was swept by the ice border streams. The channeling effects of these higher streams are not so pronounced as in other localities where the flow of water was greater in volume, of longer duration or of steeper gradient, and the limitations of the several stream levels are not all definitely mapped.

The lower channels are well marked and quite continuous. On the meridian of Victor a single capacious channel, lying between highlands both north and south, carried all the glacial drainage represented by the several channels on the east. The Victor channel heads 1½ miles southeast of Fishers with a present altitude of the channel bottom of 580 feet. The earliest stream flow in this notch must have been at some higher level, since the delta dropped by these waters northwest of Manchester, 10 miles east, is 580–560 feet. Leading east from Manchester the main channel starts 580 feet and declines to only 570 in the 7 miles to Phelps Junction. It will be seen that the fall of the streams between the Irondequoit and the Seneca valleys was very small, in consequence of which the flow must have been sluggish and the corrasional power weak. Confirmation of this is found in the shallow, flat and indefinite limitations of the channels, and in the relatively fine material composing the terminal delta.

Between Manchester and Phelps the present outlet of Canandaigua lake follows the lowest glacial channel, and it is not easy to assign the respective effects of the ancient and the modern stream work. The flow through the Victor channel continued long after the ice had left that parallel, and the latest flow probably swung northward through the swampy region of Brownville and Farmington.

All the Victor-Phelps drainage ends in a delta lying on the west side of the Seneca valley and reaching northwest from Geneva for 6 miles or to within about 1 mile of Phelps. The delta is about 1½ to 2 miles wide and declines in altitude from 600 down to 460 feet. Having a steep eastward slope it has been deeply carved by storm wash so that its delta genesis is not evident on casual inspection. Some parts of it resemble a kame moraine in form; and some moraine drift may be included in the deposit. Much of the finest detritus seems to have been borne out into the lake and spread over the low ground towards Waterloo. However, the sandy knolls which now appear over the district, and noticeable along the electric railroad, are dunes.

GLACIAL STREAM CHANNEL

Rush-Mendon channel, ½ mile east of Rochester Junction. Looking east (downstream)

SECTION OF GLACIAL STREAM DELTA

One mile northwest of Honeoye Falls. View looking east

At present it is not possible to correlate the Phelps-Geneva delta and its receiving lake with any particular outlet for the water on the east. The escape must have been 40 miles away, and probably was by the channels between Camillus and Syracuse. Possibly the channels at Elbridge and Hartlot [pl. 4] on the Skaneateles meridian, carried the primary overflow for a time. The close correlation depends on the tracing of the moraines, now very fragmental because eroded by the waters.

Most of the channels of this series are on the Onondaga limestone, which accounts partly for their shallowness, great breadth and indefiniteness of the borders; but the lowest channels in the Phelps district are down in the Camillus or gypsum group of the Salina shale.

Lower series: Fairport to Lyons

Approximately parallel with the Victor-Phelps series of channels is another water course, 6 miles north, of greater simplicity and unity. This heads at Fairport at the present altitude of 460 feet and debouches southwest of Lyons, 26 miles away in a direct line, at 400 feet elevation. The thriving towns of Fairport, Macedon, Palmyra, Port Gibson, Newark and Lyons lie in its course. The New York Central and the West Shore Railroads follow this ancient river course its whole length, as does also the Erie canal. In this connection it should be noted that the glacial waterways through western-central New York have provided the transportation lines with their remarkably uniform east and west grades.

East of Palmyra the channel splits into two, reuniting a mile farther east; but it immediately divides again and surrounds a tract of country about 3 miles in diameter, reuniting 2 miles northwest of Newark. The West Shore Railroad and the Erie canal follow the southern loop and the New York Central the northern loop.

This channel lies in the midst of the dominant drumlin area of central New York [*see* title 39] and these most remarkable and interesting forms of glacial drift border the channel on either hand. East of Palmyra the drumlins themselves do not seem to have been eroded by the stream flow, but instead the channel is somewhat below the base of the drumlins, forming a trench in the soft Salina shales. West of Palmyra some of the drumlins lie at the channel level and have been cut by the widening of the channel.

The map, plate 3, shows open channellike passages north of Newark and Lyons which are not represented as glacial drainage courses, for the reason that at some points they are so constricted

or closed by moraine or drumlin drift that they could not have carried a large volume of water, yet may be as low as the passes which are marked as glacial channels. An example is seen northeast of Newark. The Ganargua creek deserts the channel with direct or easterly course and turns north 3 miles in an open valley of channel form, then after about 5 miles of winding course to the southeast, partly in narrow cuts, returns to the old glacial channel at Lyons. It is evident, both from the directions of the stream and the valley constrictions, that the course of the Ganargua was not followed by any large volume of the latest glacial drainage. Yet the study of these low passes and others eastward to Syracuse [pl. 4] suggests that their borders are usually too definite and direct and the entire form too channellike to represent merely the accidental, irregular, low areas among the drumlins. They seem to have been originated by stream work and partially obstructed by the later ice work. With this interpretation they argue for a complicated glacial history of the region and at least more than one epoch of heavy drainage. This point has been discussed in a former writing [*see* title 39, p. 427].

The Fairport channel lies so far north of and so far beneath the Victor channel that it suggests a distinctly different epoch of the drainage. We find that between the two series of drainage courses there are no intermediate channels, although the difference in altitude is 120 to 140 feet. In the higher series we find a succession of stream cuttings within a fall of perhaps only one or two score feet. A continuous recession and falling of the barrier implies a continuous lowering of the stream work. It seems conclusive that the lower channels, the Fairport series, were not cut by drainage of the same episode, or during one continuous recession of the ice front, as the higher or Victor series. It is also evident that the Fairport channel was made later and not earlier than the Victor channel, as it has not been overridden by the glacier since its occupation by a great river.

It is certain that the Victor-Phelps channel series represents drainage past the ice border long before Lake Warren came into central New York. It seems probable that the Fairport-Lyons series is post-Warren and post-Dana in time. If this is a correct interpretation it locates approximately the position of the ice front at this stage of the hypo-Warren (or hyper-Iroquois) time, because the directness of the drainage and its relations to the low passes on the north show that it lay near the ice edge.

If the reader will assemble in order plates 3 and 4 with the intervening Weedsport sheet, not here included, he will see that the Fairport-Lyons channel is continued east as a series of low passages which probably carried post-Warren flow, although their great breadth, their depth beneath the drumlins and their burial in silts indicate that they were not wholly excavated by the last ice border drainage.

In connection with the study of the water flow in its relation to the ice barrier it must be understood that the general down-slope of the land surface at the time of the glacier recession was as much greater than today by whatever amount the surface has been differentially lifted to the northward in postglacial time. The total amount of postglacial deformation is not closely determined in this region but the Newberry plane has been tilted between 2 and 3 feet to the mile.

The Pinnacle Hills moraine at the south edge of the city of Rochester with its northwestward continuation to Brockport, Holly and Albion, and its indefinite eastward extension through the townships of Penfield and Walworth seems to mark the location of the ice border at a time not far previous to the initiation of the Fairport channel.

On plates 2 and 3 the fragmentary phenomena of Lakes Warren and Dana are shown. Plate 2 shows the Warren shore line as occurring only south of the glacial channels, probably because there were no hights of land north of the channels up to the Warren plane, about 880 feet. But numerous cliffs and spits of Lake Dana occur at 700 feet, both north and south of the channels. On plate 3 are recorded evidences of both the water planes, but here we fortunately find the Warren phenomena north of the Victor channel, on the Baker Hill kame moraine. The occurrence of wave work by Lakes Warren and Dana north of the channels and at much higher levels seems conclusive proof that the lakes were subsequent in time to the last ice border drainage.

Another evidence of the later date and imposed character of Lake Warren is found in the nature of its shore-line features. At the Warren level in central New York there are no outwash plains or glacial deltas, which should have formed if these waters had laved the ice front during its recession from the higher ground. The phenomena at the Warren level are interpreted as either wave work or land-stream construction, and the weak planes are mainly erosional. The same conclusions apply to the Dana phenomena.

The detritus washed out of the glacier into the Warren and Dana waters seems to have been deposited as kames or indefinite forms, and may not be readily distinguished from deposits of the preceding waters. The Pinnacle kame moraine probably was deposited in sub-Dana waters [pl. 15–17] escaping by the Victor channel.

The Warren and Dana planes on the Baker-Turk hills lie about 20 feet higher than to the southwest, or at 900 and 720 feet. The cause of this greater altitude is not fully determined but is partly due to the northward position.

Cayuga depr ssion: Clyde channels

Between Clyde and Weedsport lies the axis of the broad north and south depression which holds Cayuga lake. On this parallel the lowest parts of the depression are occupied by the Montezuma marshes, the western branch of which appears on the map, plate 3. Savannah is situated on an islandlike drumlin group between the two branches of the marsh.

The swamp and its streams have an altitude of about 380 feet, which is 20 feet under the passes on the east and west. In consequence of this depression the stretch between Clyde and Jordan must have been covered by shallow lake waters during the time when glacial currents swept through the passes at 400 feet. As no positive stream cutting of the latest ice border drainage can be mapped between Clyde and Jordan the entire Weedsport sheet is omitted from our plates; but its insertion between plates 3 and 4 makes the plates a complete map of the belt from Batavia to Oneida.

The low areas and somewhat irregular passes in the stretch from Palmyra to Syracuse, having both north and south and east and west directions, must have been in existence before the episode of the latest glacial drainage, which we are studying. In some places, specially where the latest ice work had partially blocked the former passes, the later drainage work can be distinguished. On the meridian of Clyde the map indicates three later channels. Close and detailed study of the district may modify this map, and perhaps find other evidences of the later ice border drainage work.

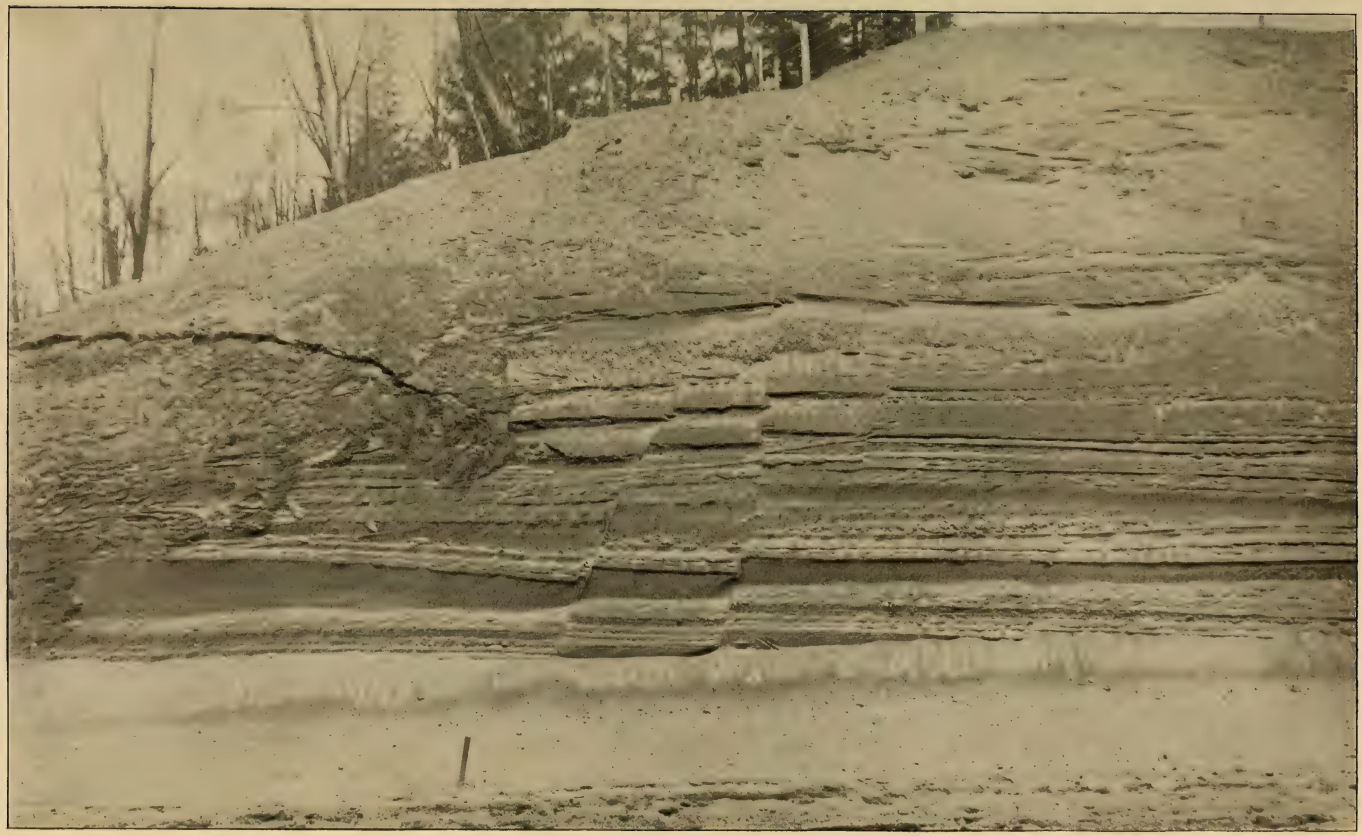
The swamp grounds in this region received the moderate volume of detrital matter which was carried by the rather sluggish drainage, and a few tracts which can be regarded as at least partly delta are designated on the map. The larger deltas are at

GLACIAL OUTWASH GRAVELS

Pinnacle kame-moraine, Rochester, N. Y. Near Erie canal widewaters. Looking southeast. Compare plate 16

GLACIAL OUTWASH GRAVELS

Pinnacle kame moraine, Rochester, N. Y. Davis pit, near pit shown in plate 15. Looking northwest



SANDS AND SILTS OF GLACIAL OUTWASH

Pinnacle kame-moraine, Goodman street cut, Rochester, N. Y. Looking east

Lyons and 3 miles southeast; and from 2 to 5 miles southeast of Clyde.

The problems of the glacial history raised by the relations of the drumlins to the open spaces and passes has been briefly considered in a former writing, describing the drumlins of New York [*see* title 39, p. 426].

Jordan-Skaneateles meridian to Syracuse

Early west-leading channels. Lake Hall

On plate 4 is depicted the more evident records of a complicated and remarkable drainage history, which can not as yet be fully translated with certainty. This is the critical district in the study of the glacial waters of central New York, since it was here that the ice sheet reposed the longest against the high ground of the southern plateau, and made its last efforts to block the glacial waters from eastward escape.

The reader will apprehend the main events in the history more readily if the fact is at once made clear that the channels west of the Syracuse meridian, as shown on plate 4, belong in three distinct episodes of the glacial drainage. In time order these are represented by:

1 The few and comparatively small west-leading channels, on the southern edge of the map.

2 The close-set series lying north of the parallel of Marcellus Falls, Howlet Hill and Onondaga Hill.

3 The two great channels east and west of Marcellus, corresponding to the latest occupation of the low passes west of Onondaga lake.

The reasons for the discordance between the chronologic and the geographic order will appear in the description following.

Earlier in time than even the first in the above outline was the overflow of the high-level glacial waters to the southward by the cols at the heads of the large valleys. This earliest glacial drainage being outside the scope of the present writing is not included in the field of the map; but will be found described in former papers [titles 16, 25].

When the ice sheet receded to the northward on the crests of the north and south ridges lying between the great valleys a westward escape for the valley lakes was opened toward Lake Newberry [*see* p. 8] and lower waters. The very lowest and latest of this episode are the two channels of group 1, leading to the Otisco valley.

Properly they do not belong in the present writing but are briefly introduced in this chapter in order to clarify the story.

Conspicuous deltas occur at the foot of Otisco lake, with their summit plateaus outlined by the contour of 940 feet. The streams which built these excellent deltas headed near Navarino and Joshua with bottom altitudes of 1140 and 1020 feet, and evidently carried westward the overflow of the ice-impounded waters of the Onondaga valley. Across the ridge east of the Onondaga valley we find a scourway at 1200 feet which carried the overflow of the Butternut valley over into the Onondaga and dropped its detritus 2 miles north of Lafayette at 1060 feet, correlating with the Navarino channel.

Looking to the west we find that the amber deltas at the foot of Otisco lake had their level determined by the hight of the overflow of the Otisco waters through a scourway 2 miles east of Skaneateles village with altitude of 940 feet. The westward outflow from the latter valley is below the field of this map, but lies at Mandana, close to the west shore of the present lake and 6 miles south of Skaneateles village, leading over to the Owasco valley, with altitude of 900 feet. Thus we find a perfectly consistent series of inflow and outflow of the glacial waters in the valleys from the Butternut westward to the Owasco.

Other west-leading channels at higher levels occur on the intervalley ridges, but they do not concern the present discussion.

The question comes, where was the ultimate outlet for these west-moving waters. In former writings it was supposed that Lake Warren was the receiving water, in central New York. But it has already been shown that the Warren waters did not invade this part of the State until subsequent to the drainage epoch represented by the east-leading channels already described, excepting perhaps the Fairport channel. The present writing is, therefore, a correction of the former supposed relation of Lake Warren.

It is apparent that the final escape of the waters must have been at a level not greatly over 900 feet, since that is about the altitude of the pass leading over to the Owasco valley. Only two possible outlets can be found. One is the Horseheads channel, at 900 feet, at the head of the Seneca valley, near the southern border of the State, the outlet of Lake Newberry; the other is the Batavia scourways, 900 feet altitude. The north and south deformation of the land since the glacial time has lifted the Newberry plane on the Skaneateles parallel not less than 80 feet above the outlet, or to

about 1000 feet. This forces us to the other alternative, the Batavia channels. To harmonize the phenomena it seems necessary to assume that the Batavia channels were effective while the ice front was yet lying against the high ground in the Syracuse region, and that all the waters bathing the ice front as far east as the Butternut valley, south of Jamesville, found westward escape. It is necessary to distinguish these waters with westward flow from the preceding Newberry lake with its southward escape and from the succeeding waters with eastward escape, and they are named Lake Hall, as already stated [*see* pl. 36].

Higher east-leading channels: Split Rock series. Lake Vanuxem

The two great channels lying west and southeast of Marcellus have heads or intakes so far beneath the level of the channels on the northeast, the Split Rock series, that it seems impossible for the waters to have been held at the hight of the latter if the Marcellus passes had then existed as low as they are today. For this reason it is believed that the Marcellus cuts were deepened to their present state subsequent to the cutting of the Split Rock channels. In chronologic order the higher and northward channels have precedence in our description.

The interesting succession of channels called the Split Rock series (named after the village and limestone quarry situated in the middle of the channels), lies on the limestone scarp southwest of Syracuse and extends from near Marcellus station, on the Auburn branch of the New York Central Railroad, eastward to Onondaga Hill and Elmwood Park. The most southerly and highest of the unequivocal channels is south of the hill crossed by the east and west highway 1½ miles southwest of Split Rock. This channel is in Marcellus shale, at an altitude of about 900 feet, according to the map contours. North of the hill and the highway the stream erosion has removed the Marcellus shale, and all the scourways down to the Split Rock gorge, or to about 750 feet, are in Onondaga and lower limestones. The bottom of the Split Rock gorge and all the channels northward are in the Cayugan (Salina) shales.

The Auburn and Syracuse Electric Railway traverses the channel district and affords a convenient way of obtaining a rapid view of the phenomena. Leaving Syracuse the electric line enters the broad, 400 foot channel at the west city line, passes through the deep gorge at Split Rock quarry, then climbs up along the face of the scarp and swings around the brow of Howlet Hill into the Marcellus valley.

The north slope of the high ground west of Marcellus station, the latter situated at the mouth of the Marcellus or Ninemile creek valley, is also extensively benched and channeled by water flow that was synchronous with the Split Rock rivers. Locally the district is known as Lime Ledge.

All the stretch of water-swept limestone from Lime Ledge east to at least the Syracuse city line, a distance of 9 miles, has been affected by postglacial sinkage of the strata, similar to that in the Caledonia-Leroy district, described on pages 12–14. The dislocation of the naked limestones is conspicuous in the channels at Lime Ledge, and it may be clearly recognized from the electric railway throughout the Split Rock district. Immediately east of the Split Rock gorge, by the first road crossing, the Salina shales are so broken that it is not easy to discriminate the forms, whether produced by sinkage and dislocation, stream work, weathering of the soft rocks, or moraine remnants. West of the city in the low channel many mounds and subdued forms, at 420 to 460 feet, which resemble moraine masses are found to be remnants of the Salina (Camillus) shales left by the ancient stream erosion and modified by weathering. In the low channels both east and west of Syracuse the eroded and weathered Salina shales are easily mistaken for moraine. This is also true of some upland surfaces, specially noted in the Canastota-Oneida region, where the drift is scanty and the land surface has not been rubbed or drumlinized by the ground-contact ice [*see* title 39, p. 431].

There is no question that all the channels of the Split Rock series, as well as all the lower channels on the north, were carved by eastward water flow. The highest unmistakable cutting is the one already noted as lying south of the Howlet Hill-Onondaga Hill highway. On the north slope of Howlet Hill and on the brow of the hill to the west the surfaces are comparatively smooth, as if water-swept, across surfaces which the map contours make 920 to 940 feet. Theoretically it seems possible that such smoothing might have been done by westward flow into Lake Hall, toward the Batavia escape. There should have been westward flow on this meridian at all levels from the Navarino channel, 1060 feet, down to the level of the Batavia channels, near 900 feet. The successors to the Navarino channels are three or four small cuts across the nose of the hill southeast of Marcellus, at about 1020 down to 960 feet. The ridge on this meridian, terminating in Howlet Hill, would seem to have been the critical and dividing line where the

ice-dammed waters hesitated or perhaps oscillated between east and west flow.

Passing by these equivocal features, we may say that the highest well marked eastward drainage in this district is at or slightly over 900 feet. Eastward, between the Onondaga, Butternut and Limestone valleys there are higher east-leading channels, to be mentioned in the next chapter.

The east and west deformation between Batavia and Syracuse, on practically the same parallel, is small, apparently 25 or 30 feet since Iroquois time. The close correspondence between the lowest passes south of Batavia and the highest at Split Rock is noteworthy, being in each case a little over 900 feet. Theoretically the Split Rock channels should be somewhat lower, and so they were when effective, or before the eastward uplift.

Three miles north of west of Marcellus is an interesting gravel plain, about a square mile in area, which includes the tract known as Shepard Settlement. It is a glacial delta or outwash by glacial streams from the edge of the glacier into standing water. On the north border the ground falls away steeply and with decidedly morainal surface, showing the ice contact. The altitude of the plain is 940 to 920 feet. The moraine forming the north side of the delta is a continuation of the Auburn moraine on the west, and seems to correlate with a belt of moraine surface which lies along the road south of the Split Rock channels. If this correlation is correct then we have located a considerable stretch of the glacier front at the time immediately preceding the initiation of the eastward flow by the highest Split Rock channels. The Shepard Settlement delta was apparently built in the waters of Lake Hall, and we thus locate the west-flowing waters far east and near the locality of subsequent eastward escape. All the relations of the several phenomena point to the history of lake and drainage as outlined above, namely that the lake waters west of the Syracuse region found westward escape at Batavia until the ice front gave way in the Split Rock district and then for a time, perhaps for many years, the central New York waters had double escape. flowing west past Batavia and east past Syracuse, either synchronously or alternately as the ice front slightly yielded or readvanced.

These waters at the ice front escaping eastward represent a lower level than Lake Hall and the opposite direction of outflow. They require a separate designation and are named Lake Vanuxem [*see* pl. 37].

Most of the higher channels of this series are shallow scourways in the limestone or only benches with low south banks. The limestone was too resistant to yield deeply to the lowering waters, but the gorge at Split Rock quarry (Solvay Process Company) and the channels east and north are down in the Salina shales and very pronounced.

The next chapter will make clear that we must postulate a readvance of the ice sheet that largely buried these channels, and subsequently with the final recession of the ice a reexcavation by the last drainage. In consequence of this repetition of stream work we can not discriminate the lower limits of the first drainage work from the second; but it must have been sufficiently low to carry the waters which cut the Victor-Phelps channels, which were under 500 feet. This seems to require that the ice should have uncovered all the land surface as far north as Jordan. Apparently all the east-leading channels depicted on the map might have been primarily excavated by the first or sub-Vanuxem drainage. The map shows the general features and relations of these channels and little further description is necessary.

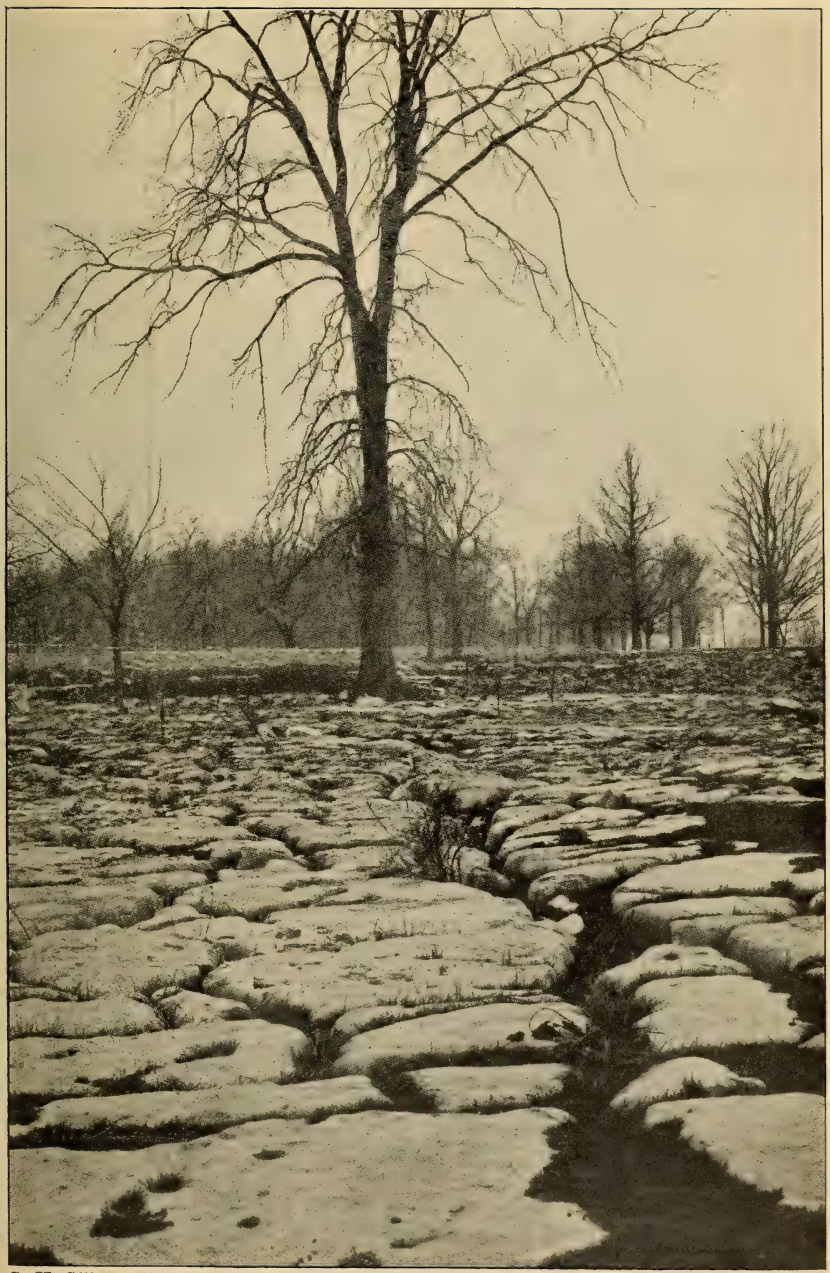
The delta at Hartlot seems to have been built in glacial waters by land drainage through Skaneateles creek; which also contributed to the Elbridge delta.

The swampy, broad, indefinite tracts followed by the railroads and Erie canal represent the lowest paths of the latest glacial drainage, probably the course also of the sub-Vanuxem drainage, and possibly a heavy flow past the on-coming ice during its invasion, or invasions, of the region. It has not seemed necessary to cover the broad low spaces with the designation or convention representing channels, as it is impossible to closely determine the limits of stream work or to separate it from lake action.

Marcellus channels: Lake Warren escape

These two great channels have been briefly described in a former writing [title 25, p. 53–55]. In that writing they were attributed to the flow of the falling Warren waters; and such is still believed to be their origin, though the present conception places them later in time than the channels, with higher altitude, on the north. The description of the channels will be in order, after which we may discuss their relations and history.

The western one of the two canyons is called, in lack of some geographic name, after the local appellation, the "Gulf." It



G. K. Gilbert, photo.

INTAKE OF GULF CHANNEL

Onondaga limestone 4 miles north of Skaneateles. Looking northeast (upstream)

G. K. Gilbert, photo.

Fig. 1 GULF CHANNEL

View looking southeast (downstream) near mouth of channel

G. K. Gilbert, photo.

Fig. 2 RAILROAD CHANNEL

Southeast of Syracuse. Looking northwest (upstream). D. L. & W. R. R. in background

heads 4 miles north of Skaneateles and a mile northwest of Shepard Settlement delta, at an elevation by the map of 820 feet. The bare limestone at the intake covers many acres, the appearance being well shown in plate 18, a characteristic view of a water-swept limestone surface. It is apparent that the great channel was not cut by merely local waters, for the features require the work of an enormous volume of water. The depth of the gorge is from 100 to 150 feet. The width of the bottom of the channel is from $\frac{1}{8}$ to $\frac{1}{4}$ mile, and the walls are flaring and not vertical, as the rocks are Marcellus shale [*see* pl. 19, fig. 1]. In the head of the gorge is a low cascade slope with two lakes (Mud Pond) at the foot. The altitude of the lakes is slightly under 800 feet and the decline of the channel bottom in the 5 miles to Ninemile creek valley is about 80 feet.

The map clearly shows how the channel widens as it joins the Ninemile (Marcellus) valley and ends in a huge fan delta. The currents of the heavy flood swung to the north through the narrow Marcellus lake to find their escape at Marcellus by the Marcellus-Cedarvale-South Onondaga channel. With the down-cutting of the latter gorge and consequent lowering of the Marcellus waters the inflowing river carved its delta into terraces with steep, curving fronts. These conspicuous erosion features on the delta can be plainly seen from the electric railway.

The highest portion of the delta, on the northwest side, reaches up to about 880 feet, and consists, as would be expected, of very coarse and poorly assorted material. The curving bluffs of erosion, representing the left-hand river banks, occurring at levels from about 860 down to about 760, mark the successive hights of the falling lake as determined by the Cedarvale outlet.

It is possible that some portion of the mass of the Gulf delta is moraine drift, as a heavy moraine lies against the delta on the south.

The body of water of small dimensions held in the Marcellus section of the Otisco valley during the life of the Gulf river has been named the Marcellus lake, it being the third in falling succession of the local glacial waters in the valley. The surface altitudes of this water were determined by the hights of the east-leading channel, the down-cutting of which accounts for the delta terraces and curving banks noted above.

The head of the Cedarville channel is at the southeast edge of the village of Marcellus, some 50 feet above the Ninemile creek,

and leads southeast with a width of $\frac{1}{4}$ to $\frac{1}{3}$ mile. The channel is in Marcellus shale except at the intake, where it reaches the Onondaga limestone. About 50 rods east of the north and south road which lies on the channel head the rock sill of the intake was cut into a cataract with a fall of about 30 to 40 feet. In the shallow and irregular basin below the cataract a lake of a few acres exists in the wet season, but is said to drain off by fissures in the limestone westward, under the cataract cliff, into the Ninemile creek [pl. 20].

The rock strata at the head of this gorge, as well as all through the region has a decided southward dip, with some flexures, the latter being well shown in the quarries in the channel head. On the north side of the intake the limestone is exposed and supports the highways, but on the south side of the intake the Marcellus shale is not entirely removed, being cut into three shallow channels with two intervening ridges, plainly seen from the north and south road. Taking as datum the United States Geological Survey bench mark on the coping of the bridge in the village, 653 feet, the elevations at the channel head are as follows: limestone at northeast angle of the channel head, over 700 feet; at the road corners, north side, 696 feet; channel in shale farthest south 685 feet.

The map shows better than verbal description the great ancient waterway, with its several branches and very extensive deltas. As a whole the channels and deltas are the most imposing among such features in New York State. The total length of the Cedarvale channel from Marcellus to the Indian Village in the Onondaga valley is nearly 12 miles, measured in its windings. All but the upper 3 miles lies in a broad preglacial valley which the river has largely filled with its delta rubbish; depositing first at the higher levels, then reexcavating and redepositing at lower and lower levels as the base level of the stream was lowered. The delta is of magnificent size and form even in its present fragmentary state. Erosion has left it in two distinct masses. The upper forms a great plateau south of Cedarvale post office, with two levels, the higher one declining in terraces from 860 feet (using the map contours) to 820 feet, the lower one being 680 to 660 feet. The preglacial valley, at least 2 miles wide on the Cedarvale meridian, must have been entirely filled with the delta, as fragments are found north of the Cedarvale channel and on the south border of the valley. That the present channel at Cedarvale, $\frac{3}{4}$ mile wide

CATARACT BASIN AND EPHEMERAL LAKE

Head of Marcellus-Cedarvale channel. Looking west (upstream). Basin is in Onondaga limestone.

in one section, has been excavated out of the former delta is proven by a conical mound of cemented gravel, over 40 feet high, standing conspicuously in the open valley a mile northwest of Cedarvale, a witness to the general filling of the old valley and the subsequent reexcavation by the falling drainage [*see* pl. 21]. The abundance of travertine in the mound suggests that the latter covers the site of an extinguished lime spring. This mound was noted, with correct interpretation, in 1842 by Vanuxem [*see* title 4, p. 247].

A stretch of open valley, ¾ of a mile square, from which the delta deposit has been removed, separates the Cedarvale portion of the delta from the larger and more scattered portion at South Onondaga and Indian Village. North and northwest of South Onondaga lies a mass over a square mile in area, the mesalike summit plateau having altitude of about 740 feet, with an eastern terrace of 670 to 660 feet; while the village lies on a 600 foot bench. A succession of erosion terraces with steep curving borders extend east and north for 3 miles, declining to the valley bottom of Onondaga creek at about 440 feet. South of the lowest channel, in which the west branch of the Onondaga creek runs, is a broad expanse of the delta filling in the higher part of the old valley, toward Cardiff, at altitude of 640 to 500 feet. The borders of the delta have received some contribution from the land stream drainage, a good illustration of which is seen south of South Onondaga where two small brooks falling 700 feet in 1½ miles have built deposits inclosing boulders in size up to 2 and 3 feet in diameter.

From some point of observation which commands a general view of the delta masses it is seen, much more plainly than the above figures for elevation indicate, that the many terraces or plains in the delta fall into three groups; the highest at 860 feet and downward, the middle (in altitude but not in geographic position) at about 750, and the lower from 680 down to 500 feet. These levels represent corresponding planes in the waters held in the valley, called the Onondaga Valley lake, and correlate of necessity with eastward outlets. We find these outlet channels on the ground southeast of Syracuse, as will be described in the next chapter.

Assuming that the great Gulf and Cedarvale channels were made by hypo-Warren waters it must be noted that the intake of the Gulf channel, 820 feet, is 60 to 70 feet beneath the plane of Lake

Warren. As there is no evidence of river work on the slopes south of the intake it appears that the initiation of eastward flow, the extinction of Lake Warren, was not in this locality. It is supposed that the Warren waters, standing over this district and creeping past the ice front, found initial outflow across one of the ridges on the east, possibly southwest of Jamesville, but more likely on the steep slope east of Jamesville, or between Fayetteville and Chittenango. Under this view the surface of the falling water was gradually lowered over the region until the river flow was established in the great channels described above.

Birth of Niagara falls and Lake Erie

During the slow fall of the hyper-Iroquois waters and while the lower Syracuse channels were occupied the second time the falls of Niagara came into existence. While the Warren and Dana waters flooded central New York these glacial waters were confluent and identical over both the Erie and Ontario basins, as far as the ice barrier was removed. The separation occurred when the escarpment of Lockport limestone emerged from the subsiding waters, thus compelling the Erian waters to cascade over the cliff and drop into the now distinct Ontarian waters. The initiation of the falls and gorge of Niagara was coincident with the creation of the primitive Lake Erie.

Dr Gilbert long ago discovered that the first spilling of the Erian waters over the escarpment found at least two points of overflow, one at Lockport and the other at Lewiston, and that the latter did not prevail until a large gulf was cut at Lockport [*see* title 11, p. 286].

It must be understood that the waters lying north of the escarpment and restricted to the Ontario basin were not yet Lake Iroquois but only the sub-Dana or hyper-Iroquois. The crest of the escarpment at the two points of initial overflow has an elevation of about 600 feet. Allowing for eastward uplift the channel passing through Fairmount and Burnet Park seems to have held the earliest river which carried waters that had fallen over the young Niagaras.

The hight of the Niagara cataract could increase only as the surface of the hyper-Iroquois waters slowly fell. The control of the Niagara base level was therefore exercised by the ice barrier resting against the Syracuse salient, and later resting on the ground east of Rochester. The several terraces found at Queenston and along

REMNANT OF ANCIENT VALLEY FILLING

Lime-cemented gravel in Marcellus-Cedarvale channel, 1 mile northwest of Cedarvale. Looking south, across the great channel. Delta plain in background

the face of the escarpment have been given names and altitudes by Dr Spencer as follows [*see* title 42, p. 197]: Roy, 533, 521 feet; Eldridge, 446; Bell, 420. To make comparison with the eastern spillways we must add to these figures about 60 feet in order to bring the Iroquois plane at Lewiston into horizontality with the same plane at Syracuse. This makes the altitudes as follows: Roy, 593, 581; Eldridge, 506; Bell, 480 feet.

It is possible to select separate channel summits which have fair correspondence with the terrace levels, but precise comparison is not of value when we consider the downcutting of the outlets; the indefinite relation of the terraces to their respective water levels; the possible slight land warping; and the minor oscillations of the ice barrier. It is sufficient to note that the Niagara terrace levels range from 600 down to 477 feet and that the later hyper-Iroquois channels range from 600 down to the Iroquois level, 440 feet.

The excellent channel leading east from the Irondequoit valley, the Fairport-Palmyra-Lyons channel, with present altitude of 460 feet, was probably the latest channel, correlating with the Bell terrace. When this outlet was effective the Iroquois water was probably established at Syracuse, and the hyper-Iroquois restricted to the territory west from Rochester [*see* pl. 41].

The volume of water carried by the channels, which was not augmented by the interposition of the cataract, was comparable to that of the St Lawrence. The smaller land area then drained was probably more than offset by the supply from the extended front of the rapidly melting glacier.

Onondaga valley to Limestone valley

This relatively short stretch of 8 miles is in one respect the most interesting of all the channel districts, since it holds remarkable extinct cataracts and plunge-basin or cataract lakes. The lower and principal channels with the cataract phenomena have been briefly described in former publications by the State [*see* titles 27, 28]. Some new facts are given here, specially concerning the higher drainage, and the map, plate 4, depicts the earlier and higher channels and gives details which the former black and white sketches did not give.

This tract covers the north ends of two great north-and-south ridges separating three deep valleys. The sudden fall of the waters which cut across the ridge between the Onondaga and Butternut valleys produced steep ravines in the limestone and one mag-

nificent cataract, the Jamesville cataract and lake[1] [pl. 22–24]. Continuing their flow across the next ridge these waters cut a series of steep gullies and cliffs along the west side of the Limestone valley south of Fayetteville and west of Manlius. One cataract and lake, Blue lake [pl. 25], comparable in size to the Jamesville lake and rock amphitheater, lies 2 miles northeast of Jamesville, while another lake, White lake, lies at the junction of the Blue lake canyon and the east and west High Bridge channel. Descriptions of these cataract lakes were published in an earlier writing and details need not be repeated here [*see* title 27, p. 126–29].

The larger and lower channels across the ridge between the Onondaga and Butternut valleys were described and illustrated in the former writings [titles 25–27]. The highest channel then recognized is the large canyon southwest of Jamesville, called the Reservoir channel, which is a deep gorge in the Marcellus shale, with a length of 3 miles, lying directly across the intervalley ridge. The altitude of the valley bottom is about 840 feet. Higher east-leading channels are now known, which are mapped on plate 4, and which are partly responsible for the circular depression formerly regarded as a loop of the Reservoir channel. The mass encircled by the glacial and recent stream flow resembles a drumlin in form, but is probably rock with a drift cap and has been shaped by the stream work and weathering. Still higher and somewhat indefinite cuts, reaching up to near 1200 feet, probably belong to an earlier time and carried local Butternut waters westward.

The most compact and remarkable set of cross-ridge channels lies north of the parallel of Jamesville. As they are all under about 800 feet they were probably originated by the outflow of the falling waters of Lake Vanuxem, and long subsequently were enlarged along with the Reservoir channel, by the much more copious waters of the falling Warren.

The lowest of the group is one of the most convincing illustrations of the work of ice-dammed waters, and in its form, preser-

[1] This lake has been described by E. C. Quereau in a paper numbered 44 in the bibliographic list. As three of the five lakes found in the Jamesville-Fayetteville district were locally called "green" lakes it was desirable to rename them. Dr Quereau renamed the one west of Jamesville the Jamesville lake. The similar lake 2 miles northeast of Jamesville the writer has renamed Blue lake [*see* title 27] since it is really a greenish blue color, and there is no near-by geographic feature to designate it. The name Green lake is allowed to stand for one of the plunge-basin lakes midway between Fayetteville and Kirkville.

CATARACT BASIN. JAMESVILLE LAKE

View looking across amphitheater from south crest. Compare plates 23 and 24

JAMESVILLE LAKE. ANCIENT CATARACT

Looking northwest, into the amphitheater. Compare plates 22 and 25

STREAM EROSION IN LIMESTONE

On south crest of Jamesville cataract. Looking northeast

ANCIENT CATARACT. BLUE LAKE

One and one half miles east of Jamesville. Looking southeast, toward the "horseshoe"

vation of features and accessibility to observation it is the handsomest glacial lake outlet channel in the State. The western end of the channel [pl. 19, fig. 2] is 3 miles southeast of the center of Syracuse, and the mouth of the cut forms a V-shaped gorge descending abruptly to the Butternut creek nearly 2 miles north of Jamesville. It is 2½ miles long, 800 to 1000 feet wide at the bottom, and 125 to 150 feet deep in rock. The nearly vertical bare walls of limestone have given it the local name of "Rock Cut," but since it is traversed by the Delaware, Lackawanna and Western Railroad, and is the only channel in the district so utilized, the name Railroad channel is more distinctive. Unlike the channels in shale, which are liable to be more or less V-shaped by the weathering and storm wash of the walls, merely the edges of the channel floor are covered by a talus. The floor is nearly level throughout, with an elevation of about 540 feet. Like the Reservoir channel it lies directly athwart the direction of the glacier movement, with both ends high in the air, the intake being 140 feet above the bottom of the Onondaga valley, less than a mile away.

The highest channel of this group is the stream-cut bluff lying along the south side of the road leading west from Jamesville, the highway resting on the rather indefinite terrace and the village being at the mouth of the shallow gorge terminating the channel. Close on the north is the canyon, cataract and lake which has been named after the village, which lies near the terminus of the gorge. Above the cataract, on the west, the limestone is worn and terraced in a manner characteristic of the swift waters of "rapids." The cataract is a semicircular amphitheater, perhaps 800 feet in diameter, with steep limestone walls 160 feet high. In the plunge-basin repose the green waters of Jamesville lake, 60 feet deep, about 400 feet wide and 500 feet long [pl. 22, 23].

Between the Jamesville canyon, 760 feet altitude, and the Railroad canyon, 540 feet, the rock is carved into a series of anastomosing channels and terraces, partially depicted on plate 4. Several plunge-basins occur in these channels, though none hold water permanently.

The large volume of delta rubbish which must have been produced by the excavation of the gorges in limestone is not found in large amount near the canyon mouths. A remnant of the boulder deposit from the Jamesville canyon is found at the northern edge of the village, and relics of the transportational work of the Railroad river lie either side of the valley road a mile north of James-

ville. The electric railway from Syracuse to Jamesville has a cutting through one of these delta fragments, as shown in plate 26.

The powerful floods of the falling waters excavated the earlier and higher delta deposits and rolled the huge boulders as well as the finer detritus to lower levels, northward, in the narrow Butternut valley. For a stretch of some 2 miles north from the mouth of the Railroad channel the valley seems to have been once filled to the width of a mile and to the depth of at least 100 feet near the head of the deposit. The most extensive remnant at the higher level is traversed by the east and west road leading to High Bridge. Lower fragments occur both sides of the valley as far as DeWitt; and a broad plain a mile northeast of DeWitt and alongside the Erie canal and its wide waters, with elevation of 440 feet, consists of coarse material and boulders up to 2 feet in diameter.

After the long weathering and soil production these coarse limestone deltas superficially resemble bouldery moraine; but dissection shows the water-worn and water-laid character of the deposit and the almost exclusively limestone composition.

The final erosion of the delta was by the lowest flow of the glacial waters and the more recent work of Butternut creek, and the material has been swept east and north to fill the low ground of the Oneida lake depression and Cicero swamp.

On this meridian, between the Onondaga and Butternut valleys, are found, certainly one and probably two more passes for glacial waters. Leading eastward from Syracuse to East Syracuse, and utilized by the several transportation lines going east, is a broad conspicuous channel, already described [*see* title 28] as the Syracuse channel. It is $\frac{1}{3}$ mile wide, and with present altitude as given by the New York Central Railroad levels of 415 feet. As it has been filled to some extent by accumulation of marl and peat its effective level was somewhat under the above figure.

North of Syracuse is a low, shallow valley, occupied by Ley creek, which connects the Onondaga valley with the low Oneida basin on the east by a divide near East Syracuse somewhat over 400 feet elevation, and toward Cicero swamp and Oneida lake by passes under 400 feet. When the ice front was in the neighborhood of Liverpool and the ice border drainage occupied the low pass by Jordan, Memphis, Warner and Amboy, the flow undoubtedly continued east by the depression of the present Onondaga lake and the Ley creek valley.

DELTA STUFF, OF GLACIAL DRAINAGE

At "Fiddler's Green," 1 mile north of Jamesville, east side of Butternut valley. Boulders are limestone derived from the railroad channel.

During the life of the Syracuse outlet the site of the city was occupied by a shallow lake extending south up the Onondaga valley, and fed by glacial waters from the west. The central and southern parts of the city are built on this detrital plain or delta built in the shallow Syracuse lake, which deposits also form the present floors of the low channels at Syracuse. These plains are at least 20 to 30 feet beneath the Iroquois level. The valleys in their deeper sections are not the erosional work of the later glacial drainage but antedate the epoch which we are studying, and as passes between the drumlin masses they are part of the problem involving all the lower channels from Palmyra to Syracuse [*see* p. 20].

In the preceding chapter the terrace levels on the Cedarvale South Onondaga delta were referred to the levels of outlets to the eastward, and we find these correlating outlets in the Jamesville series of channels. The following comparison of the levels of terraces and outlets will show the relationship.

PRINCIPAL TERRACE LEVELS ON CEDARVALE-SOUTH ONONDAGA DELTA		ALTITUDE OF OUTLET CHANNELS, JAMESVILLE SERIES	
Upper terrace	860–840	Reservoir channel	840
Mesa terrace	±750	Jamesville channel	760
Middle terrace	660		
South Onondaga terrace	640–600	Unnamed channels	700–600
Lower terrace	560	Railroad channel	540
Lowest terrace	500	Syracuse channel	400

In such comparison we must remember that the channels have suffered deepening, and that we find them with the depth attained when the river saws abandoned their work. We can not generally determine the amount of down-cutting by the stream, but no channel can be initiated at a level higher than the bottom of the antecedent and deserted channel. Another uncertain element is the relation of the lake surface to the delta terrace. A third element is the land deformation, which may not be neglected when the features are on far separated parallels. The east-west deformation in this district is small, but there may be a northward uplift of 2 or 3 feet per mile. In the above figures there is a lack of precision as they are estimated from the map contours and may vary a fraction of 20 feet, but accurate measurements will confirm the

close correspondence between the delta levels and the channels, as there can be no question of their genetic relationship.

The channels which carried the glacial flow eastward from the Jamesville district over to the Limestone valley are quite as conspicuous and interesting as those just described. As shown by the map there are a large number of distinct notches or gashes across the steep scarp between Jamesville and Manlius, the higher ones being in Marcellus shale with one lake and fossil cataract, Blue lake, rivaling the Jamesville lake and amphitheater. The Blue lake gorge leads north and joins the High Bridge channel, which is the only channel extending directly and entirely across the land between the two valleys. Three miles east of Jamesville and 2 miles southwest of Manlius is the head of an interesting ravine, with a cataract cliff about 100 feet high and an amphitheater about 50 rods across. The bottom of the ravine is a smooth meadow with two levels. The upper level is about ½ mile long, the surface being a smooth floor of fine detritus. The lower end of this meadow drops off abruptly 20 feet to another meadow, about 20 rods wide and ½ mile long, opening to the valley of Limestone creek a mile from Manlius village.

The Blue lake channel heads at about 780 feet and was cut by water in continuation of the flow of the earlier stage of the Reservoir channel. The flow through the Jamesville canyon was carried eastward by the notches cut in the scarp northeast of Jamesville and the earlier stage of the High Bridge gorge. The latter channel is a direct continuation of the Railroad channel, and the altitudes of the two channels are the same. However, since the Railroad channel ends with a deep V-shaped gorge the later flow must have found the eastward escape lower than by the High Bridge channel and therefore poured northward down the Onondaga valley, plowing away much of the earlier delta. This fact is evident on a glance at the map which shows that the Railroad channel carried all the east-flowing glacial waters until the ice front had receded 3 miles, or to the Syracuse outlet.

The production of cataracts on the west side of each valley in this region proves that the waters stood much lower in each valley, successively, than in the next valley on the west. Such discordance of the water level could not have existed if the ice front had extended in an east and west direction across the ridges and valleys. Instead of that the ice front during its last stand in this locality was part of a convexity or lobe which gave here a north-

east by southwest trend to the front, and thus allowed a sharp fall from one valley to the next one on the east.

The highest channel on the ground between the Butternut and Limestone creeks mapped in the former writings was the " Green's " channel, lying along the south side of the highway leading from Jamesville to Manlius, with altitude of about 900 feet. The present map, plate 4, represents slightly higher drainage. Much higher on the slope are cuts and scourways apparently produced by westward flow. These occur from 1 to 2 miles south of Green's channel, reaching about 1300 feet altitude. These features seem to show that even the Limestone valley waters were once tributary to Lake Newberry or Lake Hall.

The delta fragments in the Limestone valley are quite as extensive as those in the Butternut valley. They extend from Manlius northwest to below Fayetteville, on both sides of the creek, and are suggested on the map. A large remnant lies close west of Manlius and east of the creek, consisting of very coarse material and with altitude of 560 feet. A smaller fragment lies on the west side of the valley with coarser material and higher elevation since it represents the head of the original deposit. The largest fragment is northwest of High Bridge, with summit altitude of 600 feet. Some sections of the Limestone valley must have been filled clear across with the limestone rubbish, similar to the filling in the Butternut valley, with subsequent excavation of the deposits and the removal of the material northward into the low grounds.

Limestone valley to Chittenango valley

The map, plate 4, shows how completely the north-facing slope between Fayetteville and Chittenango has been swept by stream flow held betwixt the ice and the rock. On the meridian of Eagle hill, the line separating the counties of Onondaga and Madison, the whole slope is eroded, not less than 12 trenches or terraces in limestone occurring within the space of 2 miles, ranging from 1100 feet down to 500 feet [*see* pl. 27]. On the lower ground lie four more channels, in Salina shale, the lowest being a cut bank south of the Erie canal and its wide water, at the altitude of about 440 feet.

Theoretically there was some higher overflow, up to 1240 feet, as this is the altitude of the lowest of two notches west of Cazenovia lake which permitted the Limestone waters to pass eastward over to the Cazenovia and Chittenango valleys, to find further escape along the north side of Cranson hill as shown in plate 5.

The lowest channels in this district and eastward are conspicuously represented by the banks or bluffs which formed the south walls of the rivers. These are plainly seen in many places between Syracuse and Oneida from the New York Central and the West Shore Railroads, and have been described and illustrated in a former paper [title 28]. Facing the bluffs are the smooth, level surfaces that formed the floors of the latest glacial rivers of the region, and which prepared, as if purposely, the graded stretches for the canal and railroads. For considerable distances between Manlius Center and Canastota the Erie canal uses the old river bluffs for the south bank.

On the west flank of the Eagle Hill mass the water work is evident over all the saliences of the slope, but is not readily mapped. The direction of the scourways indicate the existence of an ice lobe or tongue in the Limestone valley extending up to Manlius, and beyond, and producing a curving flow of the waters around the slope north of the village. The West Shore Railroad northwest of Manlius lies along the lowest terrace.

Only one decided cataract has been found; lying 2½ miles east of Fayetteville near a north and south road, but without any lake. The drift rubbish below the cataract resembles moraine [pl. 27]. On the steep slopes southwest of Chittenango the waters cut ravines and gorges with cascades.

Two and one half miles northeast of Fayetteville are two lakes, Round and Green lakes, lying in the course of a river channel excavated in Salina shales. On account of the nonresistant character of the strata the lake basins and the valley have sloping sides and the plunge-basin origin of the lakes is not so evident as in the case of Jamesville and Blue lakes. The Round and Green lakes were probably once united but accumulation of travertine and peat has produced division.

A large volume of delta material must have been swept into the narrow Chittenango valley, north and south of the village, but mostly or entirely removed by the present stream. The absence of delta convention on the map south of the village must not be regarded as final, as close examination has not been made. Northwest of the village and north of Mycenae considerable areas are buried under stream detritus.

In the channel followed by the road between Fayetteville and Mycenae, Pools Brook hollow, are clusters of low knolls along the valley sides which might easily be mistaken for moraine, but which

CANYON OF GLACIAL RIVER

The "Basin," 2 miles northeast of Manlius. Looking northeast (downstream) from crest of cataract

are only weathered remnants of the soft Vernon beds of the Salina. It should be noted that the forms have smoother and more graceful surfaces than moraines, and that there is an almost entire absence of boulders and foreign material in the fields. In the plowed fields and stream gullies the bright green and red colors of the Vernon shales appear.

Chittenango valley to Oneida valley

The stream phenomena of this region are depicted in the map, plate 5.

This west-to-east stretch of about 12 miles includes two great ridges, Cranson hill and West Stockbridge hill, with a deep, narrow, intervening valley, Cowaselon creek or Lenox valley. The Cranson hill is on the meridian of Canastota and the West Stockbridge hill on the meridian of Oneida.

The earliest and highest channel found on the Cranson hill ridge lies a half mile southwest of the village of Perryville with a conspicuous delta plateau close to the village. The channel, which seems to have been overlooked by the topographers, is in shale, ½ mile long, 100 feet deep and with a width of bottom of 175 to 200 feet. The delta covers several acres, with two terraces, and with abrupt wall facing the village. The altitude of the channel is about 1200 feet.

The channels of the Cranson hill series proper lie on the steep slope within a belt 2 miles wide on the meridian and 6 miles long east and west. The highest channel begins ¾ mile northeast of Perryville and determined the upper level of the Perryville delta [pl. 28]. It is a winding cut in Hamilton shale with altitude of about 1230 feet, and continues around the hill as a cut terrace at about 1200 feet. The character of the stream cutting in the limestone is shown in plate 29. The lowest and longest channel in the series is down in Salina shale and forms an east and west valley nearly 6 miles long. The west half of the channel is utilized by the Elmira and Cortland division of the Lehigh Valley Railroad, while the east half of the channel is occupied by the Clockville creek, the upper waters of which come down the escarpment from the south. The village of Clockville lies where the north and south ravine bisects the east and west glacial channel.

Between the Clockville channel, altitude 800 feet at the intake, and the Canastota scourway, about 430 feet, a breadth of 2½ miles, there are four channels. These occupy the low passes in the Salina plain.

The Canastota channel is occupied by the two railroads, and the south bank of the ancient river is the conspicuous bluff close to the railroad station [*see* title 28, p. 143].

The channels on the West Stockbridge hill are fewer than on the Cranson hill, but stronger. The map shows that they have a decided curvature about the nose of the hill, indicating that lobes of ice front occupied the Cowaselon and Oneida valleys while the drainage followed the reentrant angle in the ice front on the ridge. The two southernmost channels lie on the crest of the ridge and on the south-facing slope of a limestone knob, a relationship which is singular and not understood.

One large delta has been mapped, west of the Oneida Community and south of Oneida Castle. This extensive deposit is composed largely of debris from the Salina shale in which the lower channels are cut, and the weathering and storm-wash have so dissolved and eroded the delta that in form it resembles a moraine. It is very possible that some moraine drift is buried in the delta.

The Cowaselon valley is so narrow and steep-walled that the living creek has removed the material which must have been swept into it by the Cranson hill drainage. However, the map is probably deficient in not indicating some delta deposits at Lenox and Wampsville.

DELTAS

Principles in delta construction

The many detrital deposits built in quiet waters by the contributions of the ice border drainage have been noted and briefly described in the preceding pages in connection with their correlating channels and water bodies. A few points in theoretical discussion, with application to the field under present study, will be helpful to students of the phenomena.

Theoretically, delta deposits should be expected to occur wherever a vigorous stream debouched for considerable length of time into standing water; but they are often lacking, and the question arises whether the absence of the delta is due to failure of formation or to subsequent removal.

In the study of deltas a variety and combination of modifying conditions must be considered, which may be grouped under three heads:

A Conditions relating to the stream work.

B Conditions pertaining to the delta area, or the physiography of the receiving basin.

GLACIAL STREAM CHANNEL

One mile northeast of Perryville. Looking east (downstream)

WORK OF ICE-BORDER DRAINAGE

Limestone bed of glacial river, north of Perryville. Looking eastward (downstream). The south bank of the river

MODERN STREAM WORK

Deserted bank on north side of Black river, 4 miles northeast of Watertown. Looking southwest (downstream). (Introduced for comparison with ancient drainage as shown in plates 11, 18 and 20)

C Changes subsequent to the formation of the deposits.

(*A*) The transporting ability of a stream is a function of its velocity and volume; but as streams are seldom full loaded the actual work done in the way of supplying delta material depends not only on the ability of the stream but on the quantity and quality of the detritus supplied to it. Probably none of the glacial streams represented by channels depicted on our maps lacked power to carry all the finer detritus supplied to them, but in a few localities where the flow was sluggish, as indicated by the low gradient and lack of definition in the channels, we find the stream beds littered with boulders which the currents had been unable to roll any further. Examples may be found in the indefinite channels between Victor and Phelps.

The delta-forming materials were derived from several sources: (1) Detritus from land drainage, contributed by tributary streams; (2) contributions by the glacier drainage or the outwash from the melting ice sheet; (3) glacial drift, the rock rubbish received directly from the ice by those streams which laved the ice front; (4) the glacial drift moraine and kame, which the ice and its drainage had left within reach of the stream; (5) the bed rock encountered by the stream in its down cutting, which in many cases was the most important supply.

As the streams along the ice border were cutting across ridges between the great valleys, they did not commonly drain extensive land area and consequently received relatively small contribution from tributary streams. The land-stream drainage was mainly concentrated in the larger valleys, which held glacial lakes, and which were the catchment areas for both the land-stream detritus and that of the proglacial streams. The best examples of ice border rivers with tributary land area are: at Leroy, receiving Oatka creek; at Honeoye Falls, receiving Honeoye creek; at Manchester, receiving Canandaigua inlet.

The ice border streams received their detritus mainly from two sources: (*a*) glacial drift, contributed by the melting ice front and by the streams draining the glacier, and (*b*) the product of the corrasion by the stream on its own channel. Probably the drift borne by the ice sheet had unequal horizontal distribution, and certainly the glacial drainage concentrated the drift at the points of issue or debouchment of the streams. The tendency of the streams draining the glacier to follow the valleys or land depressions beneath the ice sheet resulted in the piling of the stream detritus by the

glacial outwash mainly in the low grounds where the ice border drainage could not usually reach it. The extensive kame areas in the Genesee valley and those named the Mendon, Irondequoit, Victor and Junius [*see* title 20] are deposits formed at the ice edge and not removed.[1]

The proglacial streams naturally swept along all the ice-contributed and the ice-stream-contributed drift that came within their grasp, and little evidences of such supply would be left alongside the channels. The evidence which can be found is the considerable proportion, in some delta masses, of rock materials of northern origin, such as crystallines, Trenton limestone, Potsdam sandstone, etc. A few boulders and many cobbles of northward origin are likely to be found in all deltas, as practically every stream must have found some glacial material, either directly from the ice, or from moraine deposits along the channel sides, or contributed by land wash from the southward.

In the majority of pronounced deltas the greater part of the mass consists of material derived from the excavation of the stream channel by the corrasion of the stream itself. The amount of preglacial and glacial deposits which the stream has removed in any particular section before it could attack the rock strata could hardly be estimated, but the amount of rock cutting is quite clear. In the cases of the gorges and canyons, like the Gulf, Marcellus and Railroad channels, the large volume of rock excavation is evident, and it could be calculated approximately by measurements. The deltas at the mouths of such gorges will have a composition like the wall rocks of the canyon, and a mass proportionate to the channel excavation, provided of course that the delta has not been eroded. Sometimes the large volume or hight of the delta is the main evidence of large erosion by the stream, as in the Cedarvale-South Onondaga delta, the channel being V-shaped on account of weathering, and equivocal. Another interesting fact is that narrow north and south valleys, like those at Jamesville

[1] It should be understood that the kames (mounds of gravel and sand) are essentially deltas in the manner of their origin, being formed at the mouths of streams pouring out of the ice sheet. But they usually lack the form of deltas because of the inconstant character of the stream channels, these being walled in ice, and the shifting of the points of debouchment. Rarely in this region the glacial deltas are broad and flat, as sand plains or glacial outwash plains. One example has been described [p. 25] as the Shepard Settlement plain, another at East Bethany, Genesee co., and yet another in the same county near Darien station [*see* title 37].

and Manlius, were entirely filled with delta rubbish so that the streams swept the later detritus clear across a valley into an eastward basin. In such case the delta may represent the cutting of two or more channels on the west.

The character and size of the delta depends not only on the amount of stream erosion but also on the nature of the excavated rock. To some extent limestone is removed in solution and the shales are largely reduced to so minute division that it is borne far away. The rock strata encountered by the proglacial streams described in this paper do not include any sandstones. The higher channels, stratigraphically, are in the Marcellus shale; the middle ones in the Onondaga and upper Salina limestones; the lower ones in the lower Salina (Camillus and Vernon) shales. The deltas are found to have pronounced characteristics, dependent on the nature of the materials. Examples will be cited later.

(*B*) The building of a delta at all, and the form and extent of the deposit, depended somewhat on the topography or form of the receiving basin. When the western wall of the basin was a gentle slope the condition was favorable to the construction of broad delta plains, even of finer material, and for their preservation, like those in the Genesee valley. When, on the other hand, the receiving basin had a steep western wall, like the valleys east of Syracuse, this was unfavorable to lodgment of the detritus near the lake level, specially of the finer material, and a moderate volume of material might leave no visible delta.

If in addition to the steepness of the wall the valley is narrow and V-shaped, like those at Jamesville and in the Chittenango-Oneida district, the deposits even if large in volume may be subsequently removed.

(*C*) The changes to which the deltas have been subjected since their formation are: (1) weathering; (2) storm-wash; and (3) stream corrasion. Weathering and storm-wash have little effect on deposits of gravel or sand, and are not rapidly severe on calcareous material. It is surprising how quartzose sand deposits, beaches or deltas, have preserved their perfection of form through all the vicissitudes to which they have been exposed in the thousands of years since they were made.

If, however, the deposit is shale rubbish and therefore clayey, or even with considerable admixture of silt, then it may suffer decomposition and erosion. The delta in the Oneida valley is an excellent illustration, and the one northwest of Geneva one of less degree.

Deltas of coarse limestone rubbish, like those in the Butternut and Limestone valleys [*see* pl. 26, 31], may have accumulated a soil, which along with the frost work on the boulders, make the irregular and perhaps eroded surface resemble moraine. (It should be remembered that all these deposits have been covered with forests, which facilitated decay and soil production.)

The chief factor in the modification of the deltas has been corrasion by the later proglacial streams and their successors, the valley streams. As described earlier in this writing, the deltas of coarse limestone rubbish which once must have filled the Butternut valley at Jamesville, have been largely removed and the material swept down the creek (northward) to form extensive deposits on the edge of the Oneida lowland. In the cases of the narrow valleys on the east the same sort of work has been done in even greater degree. The excavation of the deltas was at first by the later flow of the same streams which had built the deltas, as the ice barrier receded and the base levels of the streams were lowered, and since then continuously by the existing valley streams. The lake waters in the steep-walled valleys had a minor destructive effect, as the agitation of the lowering waters tended to shift the detritus down the steep slopes.

With the principles of formation and destruction of the proglacial stream deltas before us, as outlined above, we will now review the several delta tracts in order from west to east.

Description

Genesee valley. The deltas are extensive in the Genesee valley, though the mapping, plate 2, is somewhat hypothetical as the limits are difficult to determine, even on the ground. These deltas are too broad to be conspicuous in appearance, and they blend into the uplands. At a few points their delta structure, specially the foreset beds, are grandly shown, as in the great gravel excavations at Scottsville, Canawaugus and intermediate pits [*see* pl. 7–9]. The gravels are a mixture from several sources, but those at Scottsville have a preponderance of Salina material, in which the correlating channels are cut, and are consequently of poor quality for road metal though they answer better for railroad ballast. The limestones were not deeply cut in the district west of the Genesee, though a few short gorges with cascades lie north of Leroy, and the delta material is not very coarse. The width of the Genesee valley is so great and the west wall so gently sloping that the delta deposits found favorable conditions for building and for preservation.

DELTA RUBBISH OF GLACIAL DRAINAGE

Two and one half miles north of Cazenovia, at crossing of Chittenango creek. Looking north

Rush-Mendon. The delta near Fishers built by the Rush-Mendon series of channels is well defined and not seriously eroded, though not as large as might be expected from the size and length of the stream channels. It seems probable that most of the detritus of the higher channels was partially or largely dropped in the low places along the stream courses, while that of the lower channels being Salina shales has been reduced by grinding and the product carried far away.

Victor-Phelps. The ice-border rivers in the Victor-Manchester-Clifton Springs-Phelps channels [pl. 3] had low gradient and small carrying power. They were mostly on the limestones and secured little detritus by their own corrasion. Probably a large portion of their load was used to fill low places along the stream courses and grade the channels; an illustration is the sandy plain northwest of Manchester. The final deposits of this 20 odd miles of stream flow form the somewhat anomalous and extended delta between Phelps and Geneva. This deposit of gravel and sand has a decided slope to the east and grades east and south into silts, as if it were a veneer on the valley slope. The direction of the channels and the trend of the delta seems to indicate that the ice front occupied the ground on the east. The sub-Warren waters at a later time held possession of this district, and lake silts and dune sands are spread over the surface toward Waterloo. The delta has been much gullied by storm-wash and largely eroded, as shown by the map contours, to a degree unusual for a sand-gravel deposit.

Fairport-Lyons. The splendid channel between Fairport and Lyons has no commensurate delta. For reasons already given it seems probable that the depressions occupied by the later streams were cut by the ice border drainage of an earlier ice invasion. The channel is in drift and the soft Vernon shales of the Salina, and the product of the stream corrasion in rock was not of delta-making character. Moreover such detritus as the stream obtained was spread over the low grounds in the swampy tracts to the eastward, specially along the Clyde river, beyond Lyons and southeast of Clyde.

Elbridge district. The deltas at Hartlot and Elbridge [pl. 4], as noted on page 26, seem to be chiefly the product of land drainage, by the Skaneateles outlet.

Marcellus valley. The excellent delta in the Marcellus valley at the mouth of the Gulf channel is small in area relative to the great rock channel. It is composed largely of coarse limestone derived from the intake district, and has suffered little erosion by post-

glacial agents. The gulf canyon is mostly cut in Marcellus shale and the clay detritus has been swept far on toward, or into, the Oneida lowland.

The Gulf delta is an excellent illustration of the excavating and terracing work of the river on its own deposits, produced by the lowering of its base level, as the eastern channels drained the lake waters.

Onondaga valley. The massive deposits of the Cedarvale-South Onondaga delta have already been described at some length [p. 28]. The delta tract as mapped would indicate an extent and volume of detritus beyond the amount of rock excavation suggested by the Marcellus gorge, specially as the latter is in shale. It seems probable that beneath the river deposits is considerable volume of glacial (moraine and kame) drift which the ice sheet left in the broad valley lying transverse to the ice movement; and possibly some of the broad terraces are partly erosional in drift instead of entirely constructional from stream detritus.

These great deltas were carved and reshaped by their own waters, but they seem to have much the forms with which the glacial waters left them, as subsequent activities have modified them but little. They are so vast and varied that some student of the district will find them an interesting and profitable subject for detailed work.

The many and conspicuous channels in the Split Rock district and west of Syracuse have little delta, apparently, to show for their work, the reasons being manifold. The upper channels are on the limestones and did not cut deeply. The lower channels are in Salina shales which do not contribute delta stuff. The west wall of the Onondaga valley is too steep to afford good lodgment. The coarse and heavy detritus was carried down to the bottom of the deep valley and the later, finer detritus spread over it. The valley lies at a low altitude and was occupied by Iroquois waters, and opening broadly to the north the wave work might have been effective below about 440 feet. The Onondaga creek has long been effective as a distributor of the low-lying detritus. It is probable that the silt from the South Onondaga delta and most of the detritus from the Onondaga Hill, Elmwood Park and Split Rock channels has been swept into the valley bottom to make the extended plain on which stands the city of Syracuse. The low grounds in the district of Onondaga lake must have a veneer of stream detritus over the glacial drift.

CAMILLUS CHANNEL

One of the lower channels in the Syracuse district. Altitude 420 feet. Looking southwest (upstream)

Butternut and Limestone valleys. The higher channels of the Jamesville district are in shale and therefore not favorable to deltas. The canyon of Jamesville lake and the Railroad channel supplied a great volume of limestone boulders which entirely filled the narrow Butternut valley for some distance north from Jamesville. This deposit was partially removed by the powerful currents of the lowering rivers and redeposited at lower levels farther north. The vigorous Butternut creek has aided in this work, but its burden has been carried farther out on the Oneida lowlands.

The facts briefly noted above for the Butternut valley deposits apply without important qualification to those in the Limestone valley, at Manlius and Fayetteville. The coarseness of these deposits, their large proportion of limestone, the irregularity of the surfaces, and the resemblance at first sight to bouldery moraines, are striking features.

Chittenango and Cowaselon valleys. The scouring of the limestones on the north face of Eagle hill is very pronounced, though the cutting is not extreme. The writer has not made sufficiently close examination to say that no delta fragments rest against the west wall of the valley opposite the higher channels, but the map [pl. 4, 5] clearly shows the absence of any large delta. The only deposit which has been recognized is on the low ground north and west of Chittenango, and belongs to the Pools brook and Mycenae channel. The explanation would seem to be that the deposits thrown into the Chittenango valley by the higher proglacial drainage have been rolled down the steep slopes by the postglacial storm waters and seized and swept north by the present creek.

A similar statement and explanation applies to the valley south of Canastota, and to the Cowaselon valley above Wampsville. The flat areas at Lenox seem to be Vernon shales, but some of the ground north of Wampsville should probably be marked as delta [pl. 5].

Oneida valley. The detritus held by the lowest proglacial drainage in the Chittenango-Canastota district was probably carried east past the valleys considered above and finally dropped in the Oneida valley. However, the broad delta south of Oneida Castle seems to correlate with the channels on the west, in Salina shales, and to be mainly composed of shale rubbish. It has been eroded by storm-wash to such degree that it has the aspect of a moraine,

but from favorable points of view the original plain of the delta can be recognized.

Oneida lake lowland. It seems likely that considerable areas of the lowlands east of Syracuse and north of the channels shown on plates 4 and 5 are more or less filled with deposits largely derived from the latest proglacial streams and from the deltas left in the north-leading valleys. The distribution and leveling of the materials on the plain may be largely referred to the waters of Lake Iroquois, which for some thousands of years stood here at an altitude marked today by gravel bars and spits with altitude of 440 to 450 feet. The later land drainage has also spread its load of detritus over the Iroquois bottom or carried it into Oneida lake.

Theoretic succession: summary

Theoretical succession of deposits. An ideal vertical succession of the various deposits in the district from top to bottom would be somewhat like the following, although in any actual section some numbers would be wanting and numbers 3 to 6 would be commingled. In order of time the deposits are the reverse of the numerical order.

1 Modern vegetal accumulation; peat
2 Marl, in places beneath the peat
3 Flood plain silts from post-Iroquois land drainage
4 Iroquois silts from land drainage
5 Iroquois gravels, sands and silts from erosion of glacial deltas
6 Gravels and sands directly from the glacial outwash and proglacial drainage
7 Till, ice-laid drift, directly from the glacier
8 Modified drift, gravels, sands etc., by lakes and streams during the later ice advance
9 Probable deposits, both ice-laid and water-laid, of an earlier ice invasion, perhaps a Pre-wisconsin glacial epoch
10 Geest, or products of preglacial rock decay, in place
11 Sound or live rock

Resume of delta characters. If the reader or student would examine one of the deltas which might be misinterpreted, or perhaps mistaken for moraine, he might well visit the one west of High Bridge and a mile south of Fayetteville; or the one just west of Manlius; or the one across Butternut creek from the Railroad channel; or any of the terraces in the Marcellus, Cedarvale

and South Onondaga district (as moraine drift is probably buried in these latter deltas special care may be necessary here).

His diagnosis will begin with the most obtrusive feature, the exceeding stony character of the fields. Perhaps the boulders are so large and so abundant that the surface has not been put under cultivation, like much of the delta opposite the Railroad channel. If the ground has been plowed then stone walls or fences (often a superfluous number) will likely be seen, and perhaps cairns or piles of the unused cobbles. Closer observation will reveal some degree of uniformity in the size of the stones in a restricted locality; also that they are more rounded than the ordinary stones from drift. In most of the deltas cited there is a decided preponderence of limestone, with only a small percentage of foreign material.

Noting the general form of the deposit, it will be found (if it has not been affected by subsequent erosion) to have a generally level or moderately undulating surface, quite unlike a morainic mass. In case of extremely coarse materials the delta plain might not be well developed, and erosion is possible in any case, though this produces terraces or gullies and never kettles. Toward the valley side terraces may be found with steep frontal slopes and smooth, curving horizontal lines, natural to stream erosion. Rarely on the north side of a delta the banks may be found very irregular, having been banked against the ice front, and so exhibiting the unusual constructional form of the "ice-contact."

If the position, altitude and material be referred to surrounding topography and characters, it will surely be found that the deposit has relation to some stream channel on the west. It may be some distance beyond the mouth of the channel, or near the mouth, or possibly alongside the channel which has cut through or past the delta. The altitude may not have close relation to the producing or inflow channel, but more likely to some outlet channel eastward, and possibly miles away, which determined the level of the lake waters.

In some cases of deltas of wide extent, kettles or basins may be found, which are best explained by the melting of buried ice blocks; it being supposed that in the waning of the quiescent ice front detached blocks of the stagnant ice, even of great size, might be sometimes buried in the massive stream deposits.

Usually deltas are readily distinguished by their correlation to the producing channel, but sometimes careful discrimination is required. The element most likely to be uncertain is the limits,

which in subaqueous deposits of fine material are likely to be indefinite.

OSCILLATIONS OF THE ICE FRONT: WARREN WATERS

With the above descriptions of the stream and lake features before us, it is now in order to seek the explanation which will harmonize the phenomena. A brief statement of the theoretical sequence of events was given in the introduction, but we can now elaborate some points and give a fuller account of the principal episodes in the history.

Two main facts stand out clear: first, that all the channel series from Leroy to Phelps, and all except perhaps the lowest at Syracuse, were made along the receding ice front. Second, that the Warren waters do not belong in the same episode as the channels, but that they invaded central New York long afterward. The distribution and vertical relation of the phenomena seem to permit no other conclusion.

The above conception implies, as a corollary, that the glacier, acting as a barrier, must have been adjusted to such positions as were necessary to produce the phenomena. We are required to assume some advance and retreat or oscillation of the ice front, at least in the Syracuse region, and a degree of seesawing of the ice front as between the meridians of Batavia and Syracuse. Certainly the ice barrier had to recede or back away and open low passage through Syracuse and eastward in order to allow the river flow which cut the channels. It is equally certain that when Lake Warren subsequently occupied central New York, at about 880 feet altitude, the Syracuse passes were closed [pl. 33]. But while the ice front was readvanced at Syracuse, so as to hold back the Warren waters, it was necessary in order that the waters could enter central New York at all that the ice barrier should recede in the Oakfield district.

It is seen, therefore, that we have two critical localities; one north of Batavia, near Oakfield, and the other in the Syracuse district, probably the steep slope west of the city in the district of Howlet Hill and Split Rock.

On the Split Rock meridian we find all the channels or stream flow features which the theory requires, the only undetermined feature being the hypothetical belt of moraine which might be expected to mark the limit of the ice readvance during the Warren episode. This evidence has not been diligently sought, and should

be slight since all the slope below 700 feet has been swept by the sub-Dana escape. In connection with the Warren overflow and the Dana level we will recur to this point later.

The phenomena in the western critical district are not so satisfactory. The Warren shore line lies along the crest of the Onondaga scarp from Indian Falls around to east of Batavia, at about 880 feet. The most northerly point and the highest on the beach is near the "Pond" triangulation station, 3 miles west of Oakfield, with altitude 887 feet. In this curving stretch of about 16 miles the beach phenomena are interrupted but positive, and show the lake altitude. When the ice sheet receded from the salient between Oakfield and South Byron there should have been a rush of water either east or west through the pass, unless there was a practical equality of level in the two water bodies either side of the opening, which is not impossible. The ice sheet was certainly holding the Warren waters in the Erie basin, and if the waters in central New York were much lower than the Warren then the rush of Warren waters through the new opening would have produced erosion channels below the Warren plane. On the other hand, if the ice front at Syracuse had previously readvanced and closing the east-leading passes had raised the central New York waters to a level above the Warren plane, or possibly created a second Lake Hall, then with the opening of the Oakfield pass the higher waters would have cut west-leading channels at a level above the Warren plane. But no channels have been found which answer to either case. The land surface from Indian Falls around to Morganville, east of Batavia, is irregular with drumlin and moraine drift, both above and below the Warren plane, which the Warren waves have not seriously affected. There are stretches of steep slopes and ledges beneath the beaches which might suggest river banks, but they do not have the directness or continuity of strong channel walls, while wave work was certainly present there. It is the writer's judgment that the moraines in the district are pre-Warren in time and that no stream cutting lies across the salient. It seems certain that the Warren waters invaded central New York at their full level instead of rushing in to occupy vacant territory.

Looking at the possibility of westward flow of waters superior to Warren we see that central New York waters could not stand higher than Lake Hall, slightly over 900 feet. The total possible fall from a second Lake Hall down to the Warren was only about 20 feet.

A suggestion can be offered to account for the absence of channels on the salient. It has already been stated that it is morainal territory. East of the salient and northeast of Batavia is a heavy moraine, traversed by the New York Central Railroad, with kettles and kettle lakes. To the north and northeast the land declines gently. It seems altogether probable that when the ice weakened at this locality it was not by recession of a bold and stream-swept front but by ablation and thinning over a wide belt; and that the draining of the second Lake Hall, or the waters under that level, down to the Warren plane was through stagnant and drift-buried ice, and consequently no channels are preserved.

Warren outflow

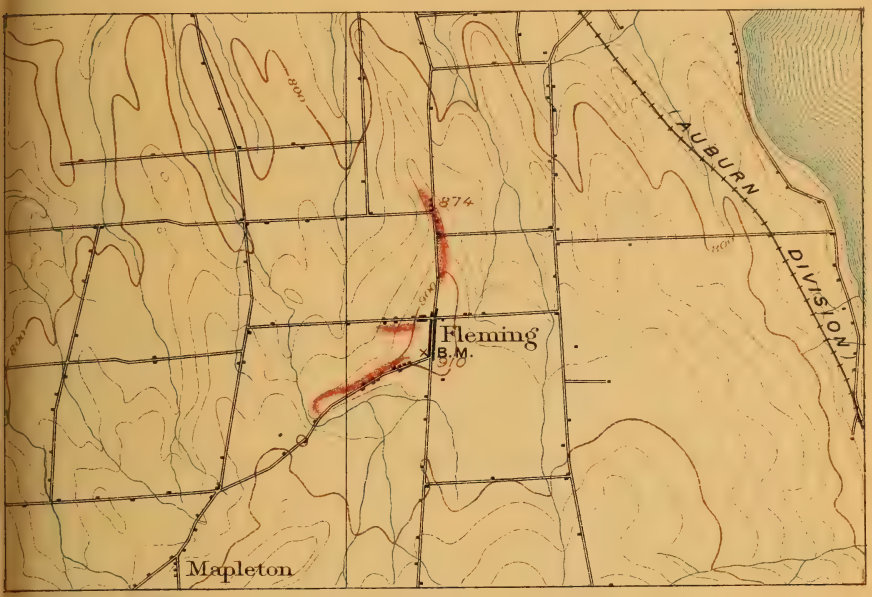
With Lake Warren admitted to the Ontario basin let us again turn our attention eastward, to the locality of its extinction, the critical district in the region of the Split Rock channels and the Gulf and Cedarvale canyons.

Our problem in this district is the production of the great canyons on the south (west and east of Marcellus) and yet subsequent to the higher (Split Rock district) channels on the north.

By a glance at plate 4 the reader will understand that the glacial waters could not have been held up to the hight of the highest channels on Howlet Hill and Split Rock if the great passes at Marcellus had then existed in the form which they exhibit today. We are forced to the conclusion that the Marcellus gorges are of later production than the Split Rock channels. The simplest explanation is to attribute the two great gorges to the overflow of the vast Lake Warren, and subsequent to the Vanuxem waters.

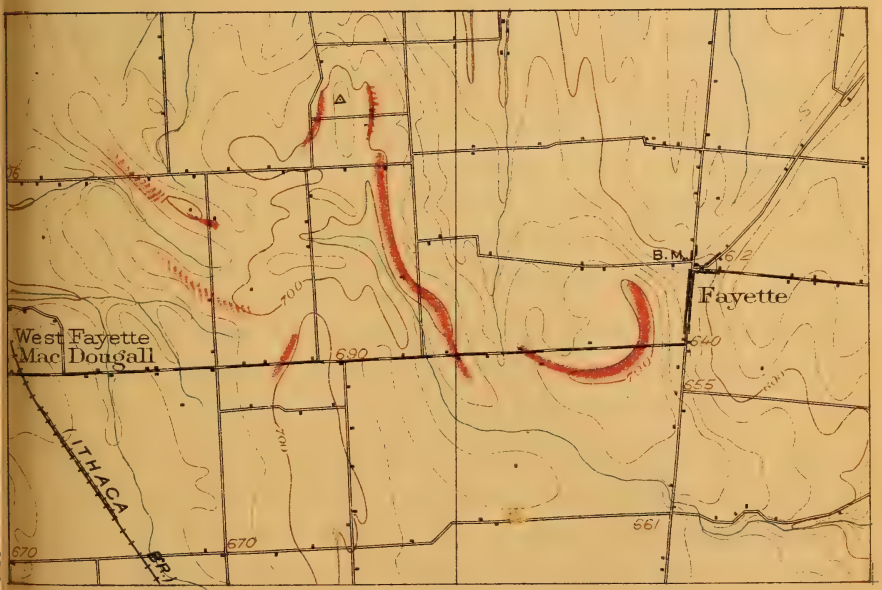
The single but sharp difficulty which we have to meet under this theory is the original hight of the Marcellus passes. When the outflow of the Vanuxem waters cut the Split Rock scourways, from 900 feet downward, the Marcellus passes must have been over 900 feet. But the later Warren waters could not have used them for outflow if they were above the Warren plane, about 880 or 890 feet. This difficulty of the altitude of the Marcellus passes is quantitatively slight, but positive.

The suggestion is now offered of a temporary filling of ice and drift in the Cedarvale-South Onondaga valley which held the pass at a high level during the life of Lake Hall and the early Lake Vanuxem. The ancient valley was sufficiently capacious



LAKE WARREN BARS

Five miles south of Auburn



LAKE DANA BARS

Six miles south of Waterloo and Seneca Falls

WARREN AND DANA BARS IN CENTRAL NEW YORK

to have held large masses of stagnant and possibly drift-buried ice, and the two sections of the valley lie so transverse to the direction of ice movement that they could readily entrap the edge of the waning ice sheet. This is not a violent nor unreasonable hypothesis, and it offers a simple and apparently the only way out of the dilemma, unless the Pleistocene history of the region is much more complex than outlined in this writing.

Lake Dana

The sub-Warren waters have been named hyper-Iroquois for the reason that they had the same ultimate escape as the Iroquois waters and were tending to the Iroquois level. The great canyons in the Syracuse region should have held the lake waters at certain levels for sufficient time, it would seem, to have produced recognizable shore features in central New York. However, the only plane of the hyper-Iroquois waters which has been found is that of Lake Dana [title 22 and pl. 2, 3], which has throughout central New York the quite uniform altitude of 700 feet [pl. 2, 33].

The only strong channel in the eastern district which could today hold the waters at near this level seems to be the Marcellus-Cedarvale canyon. To freely reach this outlet the waters must have had access to the Marcellus (Ninemile creek) valley from the north. Confirmation of this relation is found in the hight and form of the erosion at Lime Ridge, east of the head of the Gulf canyon and 3 miles northwest of Marcellus village. Under about 800 feet the limestone scarp is deeply cut into benches and channels which curve around the slope into the Marcellus valley. It would appear that when the waters of the lowering Warren fell away from the intake of the Gulf channel they flowed around the salient at Lime Ledge, and that they continued to occupy the Marcellus valley and the Cedarvale channel. This waterflow implies that the ice front had here a trend somewhat northwest by southeast; and this relation seems probable, since the drumlins indicate that during the last drumlin-making episode a lobe of the ice pushed to the southeast over the depression of Onondaga lake and Syracuse.

With the down-draining of the hyper-Iroquois water below about 700 feet, the intake of the Cedarvale canyon, the only escape was on the north slopes of Howlet hill and Split Rock and below that hight these slopes must have been water-swept the second time; and any moraine left there by the readvanced ice should be looked for above that altitude.

Theoretic lake succession [1]

In conformity with the above theory of the lake and drainage history the succession of the larger glacial lakes would be as follows:

	LAKES	APPROXIMATE ALTITUDE ON THE BATAVIA-SYRACUSE PARALLEL
1	Watkins, (Horseheads outlet, 900 feet)....	
2	Newberry (expanded Watkins).....	1000± feet
3	Hall.....	1000± down to 900± feet
4	Vanuxem.....	900± down to extinction
5	Episode of free eastward drainage and no lakes	
6	Second Vanuxem.....	rising toward 900± feet
7	Warren.....	880 feet
8	Hyper-Iroquois, Lake Dana.....	700 feet
9	Hyper-Iroquois, Lake Dawson.....	480± feet
10	Iroquois.....	440 feet

Description of the maps of glacial lake succession

Plates 34-42

This series of maps shows in a generalized and theoretical way the supposed succession of glacial waters in the central part of the State and graphically epitomizes the history discussed in the paper.

The limitations of the ice sheet are more or less hypothetical, specially in their east and west extensions, or beyond the central territory of Batavia-Syracuse. Some attempt has been made to show the lobations of the ice margin due to the larger valleys but not of the minor sinuosities. It is recognized that the ice border was not always a bold or solid front, but in some districts may have been a thinning sheet, melting to stagnant and separated masses about which the glacial waters circulated.

The glacial waters fall into three groups, as distinguished by the color shading. The succession of ice-dammed waters which were indigenous to central New York, the direct inheritance from Lake Watkins, are given horizontal shading. Those waters which originated in the Erie basin are represented by vertical shading; while those which collected in the Oneida-Rome district are expressed by oblique shading.

[1] A statement and tabulation of the episodes in the glacial lake history as affecting the Cayuga valley was printed in connection with the preliminary announcement of the special summer meeting of the American Association for the Advancement of Science held at Ithaca, N. Y., June 28–July 3, 1906.

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BULLETIN 127 PLATE 34

GLACIAL LAKE SUCCESSION IN NEW YORK STATE

by

H. L. FAIRCHILD

1908

Scale of Miles

10 5 0 10 20 30

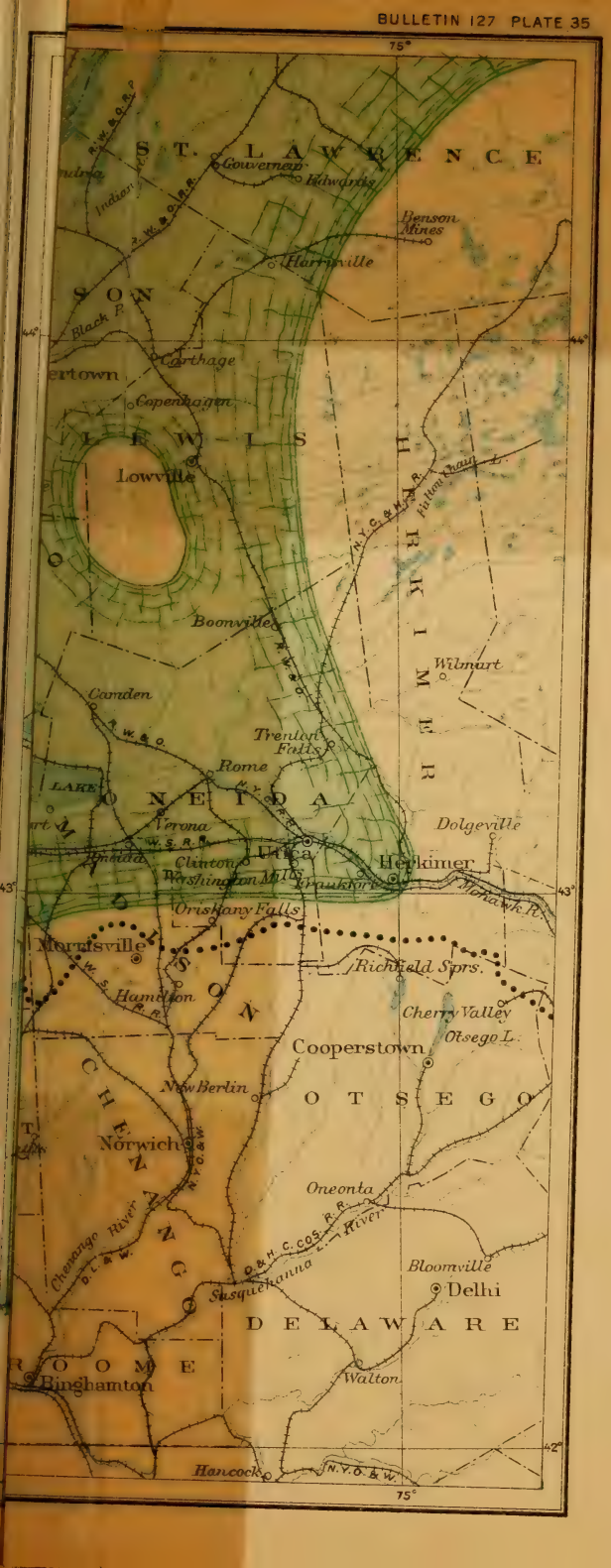
STAGE 1. LOCAL GLACIAL LAKES

Only four central lakes are shown: Naples, 1340 feet altitude; Hammondsport, 1128; Watkins, 900; Ithaca, 975. East and west of these were other lakes in the north-sloping valleys, the largest lying in the Genesee valley.

The ice margin is generalized, no attempt being made to show its conformation to the minor valleys.

Dotted line shows the divide.

79°
78°
77°
76°
75°
L A K E O N T A R I O
LAKE ERIE
Toronto
Port Hope
Kingston
Alexandria Bay
Clayton
Cape Vincent
Sacketts Harbor
Watertown
Carthage
Copenhagen
Lowville
Lorraine
Pulaski
Oswego
Fulton
Fairhaven
Sterling Star
Granby
Red Creek
Wolcott
Wallington
Ontario
Sodus
Rochester
Lyons
Newark
Syracuse
Lakeport
Brewerton
Rome
Utica
Clinton
Oriskany Falls
Herkimer
Poland
Benson Mines
Gouverneur
Edwards
Harrisville
Wilmurt
Trenton Falls
Albion
Medina
Lockport
Niagara Falls
St. Catherines
Port Colborne
Tonawanda
Batavia
Attica
Warsaw
Geneseo
Avon
Canandaigua
Geneva
Seneca Falls
Waterloo
Auburn
Skaneateles
Tully
Hamilton
Cortland
Homer
Cincinnatus
Preble
Dryden
Ithaca
Hammondsport
Watkins
Penn Yan
Dansville
Mount Morris
Belmont
Wellsville
Olean
Addison
Corning
Elmira
Owego
Binghamton
Chenango Forks
Greene
Norwich
New Berlin
Cooperstown
Cherry Valley
Otsego L.
Oneonta
Bloomville
Delhi
Walton
Hancock
Franklinville
Little Valley
Salamanca
Jamestown
Mayville
Chautauqua Lake
Canisteo
Hornellsville
Arcade
Warsaw
Perry
Castile
Silver Creek
Dunkirk
Fredonia
Westfield
Portland
Ripley
Conewango
Cattaraugus
Sandusky
Chautauqua
Allegany
Cayuga
Seneca
Tompkins
Schuyler
Steuben
Chemung
Tioga
Broome
Delaware
Otsego
Chenango
Cortland
Onondaga
Oneida
Herkimer
Lewis
Jefferson
St. Lawrence
Niagara
Orleans
Monroe
Wayne
Genesee
Wyoming
Erie
Chautauqua
Cattaraugus
Allegany
Steuben
Schuyler
Chemung
Tioga
Tompkins
Cortland
Broome
Delaware
Otsego
Chenango
Madison
Oneida
Onondaga
Oswego
Lewis
Jefferson
St. Lawrence
Franklin
Clinton
Essex
Hamilton
Fulton
Montgomery
Schoharie
Albany
Rensselaer
Saratoga
Washington
Warren
Greene
Ulster
Sullivan
Orange
Rockland
Putnam
Dutchess
Columbia
Rensselaer
Schenectady
Montgomery
Fulton
Hamilton
Saratoga
Washington
Warren
Essex
Franklin
Clinton
Greene
Ulster
Sullivan
Orange
Rockland
Putnam
Dutchess
Columbia
Albany
Schoharie


75°
ST. LAWRENCE
Gouverneur
Edwards
Benson Mines
Harrisville
Carthage
Copenhagen
Lowville
Boonville
Wilmurt
Camden
Trenton Falls
Rome
ONEIDA
Verona
Vienna
Clinton
Washington Mills
Utica
Dolgeville
Herkimer
Frankfort
Mohawk R.
Oriskany Falls
Morrisville
Hamilton
Richfield Sprs.
Cherry Valley
Otsego L.
Cooperstown
New Berlin
OTSEGO
Norwich
Oneonta
Chenango River
Susquehanna River
Bloomville
Delhi
DELAWARE
Binghamton
Walton
Hancock
N.Y.O. & W.
D. L. & W.
D. & H. C. CO'S R.R.
W. S. R.R.
N.Y.C. & H.R.R.R.
Fulton Chain
43°
42°
75°

GLACIAL LAKE SUCCESSION IN NEW YORK STATE

by

H. L. FAIRCHILD

1908

Scale of Miles

10 5 0 10 20 30

STAGE 2. LAKE NEWBERRY

An expansion of lake Watkins, having the same outlet and altitude. The outlet, through Horseheads and Elmira to the Susquehanna, is the lowest pass leading out of the Ontario basin to southern drainage.

In the Erie-Huron basin stands lake Whittlesey, having its ultimate outlet to the Mississippi; altitude at Dunkirk, 820 feet.

During this stage and the next, glacial waters were held in the Mohawk valley, but are not here indicated.

79° 78° 77° 76° 75°

L A K E O N T A R I O

L A K E E R I E

ST. LAWRENCE

JEFFERSON

LEWIS

ONEIDA

ONONDAGA

CAYUGA

SENECA

WAYNE

ORLEANS

GENESEE

NIAGARA

WYOMING

CATTARAUGUS

CHAUTAUQUA

ALLEGANY

STEUBEN

SCHUYLER

TOMPKINS

CORTLAND

CHENANGO

MADISON

OSWEGO

HERKIMER

OTSEGO

DELAWARE

CHEMUNG

TIOGA

BROOME

Kingston
Cape Vincent
Sacketts Harbor
Watertown
Lowville
Port Hope
Toronto
Oswego
Fulton
Rochester
Lyons
Syracuse
Auburn
Buffalo
Lockport
Albion
Medina
Niagara Falls
St. Catherine
Port Colborne
Batavia
Attica
Warsaw
Geneseo
Canandaigua
Geneva
Penn Yan
Naples
Dansville
Bath
Hornellsville
Watkins
Ithaca
Cortland
Norwich
Owego
Elmira
Corning
Addison
Canisteo
Wellsville
Olean
Belmont
Little Valley
Salamanca
Jamestown
Chautauqua Lake
Cuba
Franklinville
Portland
Dunkirk
Fredonia
Cattaraugus Cr.
Sandusky Cr.
Tonawanda
Tonawanda Cr.
Wallington
Ontario
Sodus
Red Creek
Wolcott
Fairhaven
Sterling
Sterling Valley
Martville
Granby
Brewerton
Oneida Lake
Rome
Trenton Falls
Utica
Verona
Clinton
Hamilton
Oriskany Falls
Morrisville
Richfield Springs
Cherry Valley
Otsego L.
Cooperstown
New Berlin
Oxford
Owaneo
Bloomville
Delhi
Wilton
Binghamton
Hancock
Canton
Potsdam
Gouverneur
Hermon
Harrisville
Carthage
Copenhagen
Lowville
Boonville
Watertown
Clayton
Alexandria Bay
Thousand Islands
Dexter
Black R.
Indian R.
Chaumont Bay
Wilmurt
Dolgeville
Herkimer
Little Falls
Ilion
Frankfort
Mohawk R.
Chenango R.
Susquehanna R.
Tioga R.
Owego Cr.
Seneca R.
Oswego R.
Oswego Falls
Fairhaven
Corden
Palatka
Lorraine
Tully
Skaneateles L.
Owasco L.
Cayuga L.
Seneca L.
Keuka L.
Crooked L.
Canandaigua L.
Honeoye L.
Conesus L.
Hemlock L.
Chautauqua L.
Erie Canal
Chemung R.
Tioga R.
Susquehanna R.
Genesee R.
Tonawanda Cr.
Sandusky Cr.
Cattaraugus Cr.
Allegany R.
Chenango R.
Oswego R.
Black R.
Indian R.
Mohawk R.
Hudson R.
Delaware R.
Schoharie Cr.
Canajoharie Cr.
Otsquago Cr.
Owasco Inlet
Cayuga Inlet
Salmon Cr.
Catatonk Cr.
Newark
Lyons
Geneva
Auburn
Syracuse
Ithaca
Watkins
Elmira
Corning
Binghamton
Owego
Rochester
Buffalo
Utica
Rome
Oswego
Watertown
Ogdensburg
Massena
Potsdam
Canton
Gouverneur
Malone
Plattsburg
Saranac Lake
Lake Placid
Tupper Lake
Saranac R.
Raquette R.
St. Regis R.
Grasse R.
Oswegatchie R.
Indian R.
Black R.
Chateaugay R.
Salmon R.
Ausable R.
Lake Champlain
Lake George
Schroon L.
Saranac L.
Raquette L.
Long L.
Blue Mountain L.
Fulton Chain
Big Moose L.
Eagle L.
Beaver R.
Moose R.
Stillwater
Saratoga
Glens Falls
Whitehall
Fort Edward
Hudson Falls
Troy
Albany
Schenectady
Amsterdam
Gloversville
Johnstown
Little Falls
Herkimer
Ilion
Frankfort
Mohawk
Hoosick Falls
Cohoes
Waterford
Green Island
Watervliet
Rensselaer
Hudson
Catskill
Coxsackie
Athens
Kinderhook
Chatham
Lebanon Springs
Pittsfield
Lenox
Stockbridge
Great Barrington
Sheffield
Canaan
Salisbury
Lakeville
Winsted
Torrington
Litchfield
Bantam L.
Waramaug L.
Candlewood L.
Housatonic R.
Naugatuck R.
Shepaug R.
Pomperaug R.
Still R.
Farmington R.
Connecticut R.
Westfield R.
Deerfield R.
Millers R.
Miller's R.
Nashua R.
Merrimack R.
Contoocook R.
Ashuelot R.
Connecticut L.
Monadnock
Mount Washington
Mount Lafayette
Mount Lincoln
Mount Garfield
Mount Jefferson
Mount Adams
Mount Madison
Mount Clay
Mount Monroe
Mount Franklin
Mount Pleasant
Mount Willard
Crawford Notch
Franconia Notch
Profile L.
Echo L.
Lafayette R.
Pemigewasset R.
Winnipesaukee R.
Winnipesaukee L.
Squam L.
Newfound L.
Asquam L.
Ossipee L.
Ossipee R.
Saco R.
Androscoggin R.
Androscoggin L.
Umbagog L.
Rangeley L.
Kennebec R.
Dead R.
Moosehead L.
Penobscot R.
Penobscot L.
Chesuncook L.
Allagash R.
Allagash L.
St. John R.
St. Francis R.
St. Francis L.
Lake Memphremagog
Lake Champlain
Lake George
Lake Ontario
Lake Erie
Lake Huron
Lake Michigan
Lake Superior
Lake Winnipeg
Lake of the Woods
Rainy L.
Rainy R.
Nipigon L.
Nipigon R.
Lake Nipissing
Lake Temiskaming
Lake Abitibi
Lake Timagami
Lake Kenogami
Lake Mistassini
Lake St. John
Lake Manicouagan
Lake Nichicun
Lake Albanel
Lake Mistassibi
Lake Waswanipi
Lake Evans
Lake Matagami
Lake Opasatika
Lake Kesagami
Lake Abitibi
Lake Timiskaming
Lake Nipissing
Lake Temagami
Lake Kenogami
Lake Mistassini
Lake St. John
Lake Manicouagan
Lake Nichicun
Lake Albanel
Lake Mistassibi
Lake Waswanipi
Lake Evans
Lake Matagami
Lake Opasatika
Lake Kesagami

EDUCATION DEPARTMENT
JOHN M. CLARKE
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GLACIAL LAKE SUCCESSION IN NEW YORK STATE

by

H. L. FAIRCHILD

1908

Scale of Miles

10 5 0 10 20 30

STAGE 3. LAKE HALL

Successor to lake Newberry; outlets leading westward past Batavia, with altitudes falling from about 1000 down to 900 feet. The map indicates the latest phase. The overflow was to lake Warren, the successor in the Erie-Huron basin of lake Whittlesey; escape to the Mississippi; altitude of Warren at the ice front about 860 feet.

79°
78°
77°
76°
75°
44°
43°
42°
L A K E O N T A R I O
LAKE ERIE
ONTARIAN
ERIE
Kingston
Port Hope
Toronto
Cape Vincent
Sacketts Harbor
Watertown
Alexandria Bay
Clayton
Gouverneur
Edwards
Benson Mines
Harrisville
Carthage
Copenhagen
Lowville
Pulaski
Boonville
Oswego
Fairhaven
Sterling Station
Fulton
Mannsville
Red Creek
Wallington
Camden
Trenton Falls
Wilmurt
Albion
Medina
Lockport
St. Catherines
Niagara Falls
Tonawanda
Port Colborne
BUFFALO
Attica
Warsaw
Portage
Cattaraugus
Sandusky
Olean
Little Valley
Salamanca
Jamestown
Chautauqua Lake
Belmont
Caba
Franklinville
Hornellsville
Bath
Addison
Corning
Elmira
Waverly
Canisteo
Wallington
ROCHESTER
Lyons
Newark
Clyde
Syracuse
Oneida Lake
Brewerton
Lakeport
Verona
Oneida
Utica
Rome
Dolgeville
Herkimer
Frankfort
Mohawk R.
Washington Mills
Oriskany Falls
Morrisville
Hamilton
Tully
Cortland
Cincinnatus
Homer
New Berlin
Norwich
Cooperstown
Richfield Spgs.
Cherry Valley
Otsego L.
Oneonta
Unadilla River
Susquehanna River
Bloomville
Delhi
Walton
Binghamton
Owego
Ithaca
Watkins
Penn Yan
Naples
Pratts burg
Hammondsport
Honeoye
Canandaigua
Geneseo
Avon
Livonia
Mount Morris
Dansville
Nunda
Portage
Cuba
Belmont
Allegany R.
Chemung R.
Tioga R.
Susquehanna R.
Chenango River
Cassadaga L.
Chautauqua L.
Conesus L.
Honeoye L.
Canandaigua L.
Seneca L.
Cayuga L.
Owasco L.
Otisco L.
Skaneateles L.
Crooked L.
Keuka L.
Waterloo
Auburn
Owasco Lake
Skaneateles
Otisco
Tully
Cortland
Norwich
Oneonta
Bloomville
Delhi
Walton
Hancock
Binghamton
Owego
Elmira
Corning
Addison
Waverly
Watkins
Ithaca

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1908

Scale of Miles

10 5 0 10 20 30

STAGE 4. LAKE VANUXEM

Successor to lake Hall; outlets at Syracuse to the Mohawk-Hudson; altitudes from 900 feet downward. An early phase is represented, with altitude about 800 feet. Lake Warren is still confined to the Erie basin.

GLACIAL LAKE SUCCESSION IN NEW YORK STATE

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Scale of Miles

10 5 0 10 20 30

STAGE 5. FREE DRAINAGE

Small glacial lakes held in the Genesee and the Cayuga valleys. (see plates 2 and 3.)

Following this stage the ice readvanced at Syracuse and restored lake Vanuxem. (Stage 6 would be mapped similar to stage 4.)

79° 78° 77° 76° 75°

46° 43° 42°

L A K E O N T A R I O

L A K E E R I E

ONTARIAN ICE LOBE

S T . L A W R E N C E

Kingston
Alexandria Bay
Clayton
Gananoque
Edwards
Benson Mines
Harrisville
Cape Vincent
Black R.
Watertown
Carthage
Copenhagen
Sackets Harbor
Port Hope
Toronto
Lowville
Lorraine
Boonville
Wilmurt
Oswego
Fairhaven
Sterling Sta.
Fulton
Camden
Trenton Falls
Rome
Wallington
Red Creek
Ontario Sodus
Walcott
Marcellus
Albion
Lockport
Medina
Tyrone
Dolgeville
St. Catherine
Niagara Falls
Tonawanda
Lewiston
Herkimer
Port Colborne
Batavia
Syracuse
Oriskany Falls
Canandaigua
Geneva
Clyde
Seneca Falls
Auburn
Marrisville
Richfield Spgs.
Warsaw
Attica
Genesee
Moscow
Penn Yan
Oyad
Cortlandt
Cooperstown
Cherry Valley
Otsego L.
New Berlin
Norwich
Waples
Prattsburg
Hammondsport
Portage
Dansville
Sandusky
Cattaraugus
Ithaca
Oneonta
Hornellsville
Bath
Watkins
Bloomville
Delhi
Mayville
Chautauqua Lake
Little Valley
Jamestown
Salamanca
Franklinville
Cuba
Belmont
Canisteo
Wellsville
Addison
Corning
Elmira
Owego
Binghamton
Walton
Hancock

WYOMING
LIVINGSTON
GENESEE
MONROE
WAYNE
ONTARIO
ORLEANS
NIAGARA
ERIE
JEFFERSON
LEWIS
OSWEGO
ONONDAGA
CAYUGA
SENECA
YATES
TOMPKINS
SCHUYLER
CHEMUNG
TIOGA
BROOME
CHENANGO
CORTLANDT
MADISON
OTSEGO
DELAWARE
STEUBEN
ALLEGANY
CATTARAUGUS
CHAUTAUQUA

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Scale of Miles

10 5 0 10 20 30

STAGE 7. LAKE WARREN

While the second lake Vanuxem (stage 6) was held in central New York the ice front north of Batavia receded so as to permit lake Warren to spread eastward and occupy Vanuxem territory; altitude on the Batavia parallel about 880 feet; outlet to the Mississippi.

79° 78° 77° 76° 75°

L A K E O N T A R I O

ONTARIAN ICE LOBE

LAKE ERIE

Kingston
Port Hope
Toronto
Cape Vincent
Sacketts Harbor
Watertown
Lowville
Harrisville
Black R.
Indian
Clayton
Alexandria Bay
Benson Mines
Canton
Edwards
Oswego
Fulton
Pulaski
Boonville
Camden
Wilmurt
Trenton Falls
Rome
Utica
Herkimer
Dolgeville
Little Falls
Fairhaven
Sterling Sta.
Martville
Red Creek
Wolcott
Wallington
Ontario Sodus
Lyons
Syracuse
Oneida
Chittenango
Canastota
Oriskany Falls
Morrisville
Hamilton
Richfield Spgs.
Cherry Valley
Otsego L.
Cooperstown
New Berlin
Norwich
Oneonta
Cortland
Cincinnatus
Albion
Lockport
Niagara Falls
Medina
Rochester
Batavia
Buffalo
Port Colborne
St. Catharines
Attica
Warsaw
Genesee
Mosco
Canandaigua
Penn Yan
Waterloo
Geneva
Seneca Falls
Auburn
Tully
Owasco L.
Skaneateles L.
Waples
Prattsburg
Dansville
Hammondsport
Keuka L.
Ithaca
Watkins
Hornellsville
Bath
Canisteo
Addison
Corning
Elmira
Chemung R.
Owego
Binghamton
Walton
Bloomville
Delhi
Susquehanna R.
Chenango River
Tioga R.
Tioga
Wellsville
Belmont
Alfred
Cuba
Olean
Salamanca
Jamestown
Little Valley
Chautauqua Lake
Panama
Frankinville
Cattaraugus Cr.
Sandusky
Gowanda
Hancock
Tioga Junction
Waverly
Lackawanna R.
Chemung R.
Genesee River
Canaseraga
Hemlock L.
Honeoye
Canandaigua L.
Seneca L.
Cayuga L.
Owasco L.
Otisco L.
Skaneateles L.
Onondaga L.
Oneida L.
Chautauqua L.
Conewango Creek
Allegheny R.
Conewango Creek
Chautauqua Lake
Oneida River
Fish Creek
Chittenango Creek
Limestone Creek
Oneida Creek
Onondaga Creek
Seneca River
Cayuga Inlet
Catatonk Creek
Susquehanna R.
Chenango River
Tioga R.
Cohocton R.
Canisteo R.
Genesee River
Oatka Creek
Honeoye Creek
Canaseraga Creek
Hemlock L.

GLACIAL LAKE SUCCESSION IN NEW YORK STATE

by

H. L. FAIRCHILD

1908

Scale of Miles

10 5 0 10 20 30

STAGE 8. LAKE DANA

A final recession of the ice front at Syracuse gave the Warren waters an eastward escape to the Mohawk-Hudson. The Dana stage was only a long pause in the fall of the waters (Hyper-Iroquois) from the Warren to the Iroquois (Rome outlet) level. Outlet of the Dana stage at Marcellus, 700 feet.

LAKE ONTARIO

ONTARIAN ICE LOBE

LAKE ERIE

Kingston
Port Hope
Toronto
Cape Vincent
Sackets Harbor
Watertown
Black R.
Carthage
Copenhagen
Lowville
Lowville
Harrisville
Benson Mines
Edwards
Gouverneur
Brasher
Indian R.
Clayton
Alexandria Bay
Lorraine
Pulaski
Oswego
Fulton
Hastings
Mexico
Fairhaven
Sterling
Martville
Camden
Boonville
Trenton Falls
Wilmurt
Holland Patent
Home
Dolgeville
Herkimer
Frankfort
Ilion
Clinton
Washington Mills
Oriskany Falls
Oneida
Verona
Sherrill
Rockwell
Rockwell Springs
Cherry Valley
Otsego L.
Cooperstown
New Berlin
Morrisville
Hamilton
Tully
Skaneateles
Skaneateles L.
Otisco L.
Otisco
Onondaga
Cortland
Norwich
Oneonta
Bloomville
Delhi
Walton
Hancock
Binghamton
Owego
Elmira
Corning
Addison
Canisteo
Hornellsville
Bath
Watkins
Ithaca
Cayuga
Seneca
Geneva
Canandaigua
Naples
Penn Yan
Dansville
Prattsburg
Hammondsport
Keuka L.
Seneca L.
Cayuga L.
Owasco L.
Auburn
Syracuse
Oswego
Fulton
Phoenix
Baldwinsville
Jordan
Weedsport
Port Byron
Rochester
Ontario
Sodus
Wolcott
Lyons
Clyde
Newark
Palmyra
Macedon
Fairport
Pittsford
Brighton
Irondequoit
Albion
Lockport
Medina
Niagara Falls
Tonawanda
St Catharines
Port Colborne
Buffalo
Batavia
Attica
Warsaw
Genesee
Avon
Mt Morris
Dansville
Portage
Cuba
Belmont
Allegany
Olean
Salamanca
Little Valley
Cattaraugus
Sandusky
Dunkirk
Fredonia
Mayville
Chautauqua Lake
Jamestown
Franklinville
Wellsville
Alfred
Hemlock L.
Canadice L.
Honeoye L.
Conesus L.
Canaseraga
Genesee River
Chemung River
Susquehanna River
Tioga
Broome
Chenango
Otsego
Delaware
Schuyler
Yates
Ontario
Wayne
Monroe
Livingston
Steuben
Allegany
Cattaraugus
Chautauqua
Genesee
Orleans
Niagara
Erie
Jefferson
Lewis
St. Lawrence
Franklin
Essex
Hamilton
Herkimer
Oneida
Onondaga
Cortland
Chenango
Madison
Otsego
Delaware
Schoharie
Montgomery
Fulton
Saratoga
Warren
Washington
Rensselaer
Albany
Greene
Ulster
Sullivan
Orange
Rockland
Putnam
Dutchess
Columbia
Westchester
Bronx
New York
Kings
Queens
Richmond
Nassau
Suffolk
Erie Canal
Champlain Canal
Black River Canal
Oswego Canal
Cayuga and Seneca Canal
Chenango Canal
Chemung Canal
Crooked Lake Canal
Delaware and Hudson Canal
Delaware and Hudson R.R.
New York Central and Hudson River R.R.
West Shore R.R.
Lehigh Valley R.R.
Erie R.R.
Delaware, Lackawanna and Western R.R.
Rome, Watertown and Ogdensburg R.R.
Utica and Black River R.R.
Ogdensburg and Lake Champlain R.R.
Rutland R.R.
Central Vermont R.R.
Boston and Maine R.R.
Lehigh and New England R.R.
Central New England R.R.
New York, Ontario and Western R.R.
Ontario and Western R.R.
Buffalo, Rochester and Pittsburg R.R.
Pennsylvania R.R.
Buffalo, New York and Erie R.R.
Lake Shore and Michigan Southern R.R.
Lake Erie and Western R.R.
Toledo, Peoria and Western R.R.
Wabash R.R.
Grand Trunk R.R.
Canadian Pacific R.R.
Michigan Central R.R.
Canada Southern R.R.
Wheeling and Lake Erie R.R.
Pittsburg, Shawmut and Northern R.R.
Pittsburg, Bradford and Buffalo R.R.
Allegheny River R.R.
Tioga R.R.
Fall Brook R.R.
Cortland and Syracuse R.R.
Cortland and Northern R.R.
Utica, Chenango and Susquehanna Valley R.R.
Delaware, Lackawanna and Western R.R.
Syracuse, Binghamton and New York R.R.
Ithaca and Cortland R.R.
Ithaca and Owego R.R.
Elmira, Cortland and Northern R.R.
Elmira and Lake Ontario R.R.
Elmira, Jefferson and Canandaigua R.R.
Northern Central R.R.
Baltimore and Ohio R.R.
Philadelphia and Reading R.R.
Central R.R. of New Jersey
Lehigh and Hudson River R.R.
New York and Greenwood Lake R.R.
Erie and Pittsburg R.R.
Pittsburg and Lake Erie R.R.
Pittsburg and Western R.R.
Bessemer and Lake Erie R.R.
Buffalo and Susquehanna R.R.
Buffalo, Rochester and Pittsburg R.R.
Buffalo, New York and Erie R.R.
Lake Shore and Michigan Southern R.R.
Lake Erie and Western R.R.
Toledo, Peoria and Western R.R.
Wabash R.R.
Grand Trunk R.R.
Canadian Pacific R.R.
Michigan Central R.R.
Canada Southern R.R.
Wheeling and Lake Erie R.R.
Pittsburg, Shawmut and Northern R.R.
Pittsburg, Bradford and Buffalo R.R.
Allegheny River R.R.
Tioga R.R.
Fall Brook R.R.
Cortland and Syracuse R.R.
Cortland and Northern R.R.
Utica, Chenango and Susquehanna Valley R.R.
Delaware, Lackawanna and Western R.R.
Syracuse, Binghamton and New York R.R.
Ithaca and Cortland R.R.
Ithaca and Owego R.R.
Elmira, Cortland and Northern R.R.
Elmira and Lake Ontario R.R.
Elmira, Jefferson and Canandaigua R.R.
Northern Central R.R.
Baltimore and Ohio R.R.
Philadelphia and Reading R.R.
Central R.R. of New Jersey
Lehigh and Hudson River R.R.
New York and Greenwood Lake R.R.
Erie and Pittsburg R.R.
Pittsburg and Lake Erie R.R.
Pittsburg and Western R.R.
Bessemer and Lake Erie R.R.
Buffalo and Susquehanna R.R.

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IN
NEW YORK STATE
by
H. L. FAIRCHILD
1908

Scale of Miles
30 5 0 30 20 30

STAGE 9. LAKE DAWSON

The lowest and latest of the Hyper-Iroquois waters; outlet by the Fairport-Palmyra channel into the primitive lake Iroquois; altitude 460 feet.

Niagara cataract and lake Erie now initiated.

79° 78° 77° 76° 75°

Kingston
Cape Vincent
Port Hope
Toronto
Sackets Harbor
Watertown
Lowville
Harrisville
Alexandria Bay
Clayton
Edwards
Benson Mines
Lorraine
Boonville
Wilmurt
Trenton Falls
Rome
Dolgeville
Herkimer
Oriskany Falls
Morrisville
Richfield Spgs.
Cherry Valley
Otsego L.
Cooperstown
New Berlin
Norwich
Oneonta
Bloomville
Delhi
Walton
Hancock
Syracuse
Auburn
Seneca Falls
Oswego
Fairhaven
Wolcott
Sterling
Red Creek
Wallington
Wayne
Marcellus
Skaneateles
Otisco
Tully
Cortlandt
Cincinnatus
Ithaca
Watkins
Elmira
Corning
Addison
Binghamton
Owego
Waverly
Hammondsport
Keuka Lake
Penn Yan
Waterloo
Geneva
Canandaigua
Seneca Lake
Clyde
Lyons
Newark
Palmyra
Fairport
Pittsford
Rochester
Albion
Medina
Lockport
Niagara Falls
Tonawanda
Buffalo
Port Colborne
St. Catherines
Batavia
Attica
Genesee
Warsaw
Wyoming
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Dansville
Geneseo
Mt. Morris
Hornellsville
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Alfred
Belmont
Wellsville
Olean
Salamanca
Jamestown
Chautauqua Lake
Mayville
Dunkirk
Fredonia
Cattaraugus
Sandusky
Franklinville
Little Valley
Cuba
Warren
Kinzua
Allegany R.
Chemung R.
Susquehanna R.
Tioga R.
Owego
Hamilton
Clinton
Washington Mills
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Verona
Oneida
Chenango River
Otselic R.
Otselic
Tully
Skaneateles
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Onondaga L.
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Cayuga L.
Keuka L.
Crooked L.
Canandaigua L.
Honeoye L.
Conesus L.
Hemlock L.
Canadice L.
Chautauqua L.
Allegany R.
Conewango Cr.
Tonawanda Cr.
Oatka Cr.
Genesee R.
Black R.
Oswegatchie R.
Indian R.
Raquette R.
St. Lawrence R.
Erie Canal
Chenango Canal
Crooked Lake Canal
Barge Canal
Lehigh Valley R.R.
N.Y.C. & H.R.R.R.
L.V.R.R.
W.S.R.R.
D.L.&W.
N.Y.L.E.&W.
W.N.Y.&P.
B.R.&P.
N.Y.O.&W.
C.N.Y.C.O.&S.R.R.
C.&N.C.&S.R.R.
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C.&P.R.R.
C.&S.R.R.
N.Y.C.&H.R.R.
N.Y.S.&W.R.R.
N.K.&W.
Cort.&N.R.R.

L A K E O N T A R I O

ONTARIAN ICE LOBE

PRIMITIVE LAKE ERIE

ST. LAWRENCE
JEFFERSON
LEWIS
HERKIMER
ONEIDA
ONONDAGA
CAYUGA
SENECA
WAYNE
MONROE
ORLEANS
NIAGARA
GENESEE
LIVINGSTON
WYOMING
YATES
STEUBEN
ALLEGANY
CATTARAUGUS
CHAUTAUQUA
SCHUYLER
TOMPKINS
CHEMUNG
TIOGA
BROOME
CHENANGO
OTSEGO
DELAWARE
MADISON
CORTLANDT

79° 78° 77° 76° 75°

EDUCATION DEPARTMENT
JOHN M. CLARKE
STATE GEOLOGIST

GLACIAL LAKE SUCCESSION IN NEW YORK STATE

by

H. L. FAIRCHILD

1908

Scale of Miles

10 5 0 10 20 30

STAGE 10. LAKE IROQUOIS

The early phase of the lake with full westward extension; altitude then under 360 feet.

The waning of the ice sheet eventually permitted the lake to occupy the entire basin.

The areas of the lake waters are indicated in only a general way, it being impossible in such small maps to show minor features. A special difficulty in mapping the ancient shore lines is due to the land warping. The northward uptilting of the Ontario basin was probably in progress during the time of the waning of the ice sheet and has continued down to the present. This progressive uplift makes it impossible to closely assign the proportionate deformation for the individual lakes. The slant of the Newberry plane is estimated at about 2 feet per mile on the average, and the lake areas are here mapped on that basis; the Newberry plane rising from about 900 feet at Horseheads (the channel bottom) to about 1000 feet toward the Batavia parallel.

The matter of the glacial water levels is further complicated by some east and west deformation. We have as yet no clear measure of the warping in that direction previous to Iroquois time, though the Warren beaches indicate that it was not large. The long west to east stretch of the south shore of Iroquois and its mature character give us a fair measure of the post-Iroquois deformation. Altitudes on the Iroquois shore are as follows: Hamilton, Ont., 362 feet above tide; Lewiston, 383; Lockport, 402; Gaines, 430; Sodus, 456; Rome, 460. From Hamilton to Sodus is about 138 miles, with equal latitude, and the rise of the water plane is 0.68 feet per mile, or something over 8 inches. From Sodus to Rome, in direction only slightly south of east, and the distance about 82 miles, the deformation is practically nothing. It is apparent that since Lake Iroquois was drained away the Sodus-Rome district has been lifted about 100 feet more than the west end of the basin.

To restore the geographic conditions that existed during the ice retreat we must depress the Rome end of the basin about 100 feet. This fact, coupled with the low channels in the Syracuse district prove that in pre-Iroquois time there was free drainage to the Mohawk valley, as shown in stage 5 [pl. 38]. The col at Rome is partly due to differential uplift and partly to delta filling by the upper Mohawk river in the glacial waters held in the Mohawk valley.

The altitude figures given in the descriptive legends on the maps refer to the present altitudes.

SUMMARY OF THE GLACIAL DRAINAGE HISTORY

1 All the glacial waters of the Lake Erie basin down to and including Lake Warren escaped westward to the Mississippi.

The lowering Warren and all subsequent waters flowed eastward to the Mohawk-Hudson.

2 The pre-Warren waters in central New York had a complicated history with varying levels and different outlets. These waters fall into two provinces; those tributary to the Seneca valley, the glacial Lake Newberry [pl. 35], with southward escape at 900 feet through Horseheads to the Chemung-Susquehanna; and those tributary to the Genesee valley. The higher waters of the latter area oscillated between escape to the Allegany-Mississippi and to the Susquehanna, but under 1200 feet and down to about 900 feet, the altitude of the scourways at Batavia, the Genesee waters escaped westward to the Warren lake. Between the now tilted plane of Lake Newberry, about 1000 feet on the Batavia parallel, and 900 feet, the Batavia scourways, all the waters of the Seneca basin area as well as the Genesee area poured westward into Lake Warren.

3 The west-flowing waters with outlets on the Batavia meridian across to Lake Warren, from about 1200 feet, have been called in a former writing the Seventh Stage, or Warren Tributary Stage of the Genesee glacial lakes. It is now proposed to differentiate the waters standing between the Newberry plane, about 1000 feet at Batavia, and the plane represented by the 900 feet scourways at Batavia and give it a distinctive name, for the reason that it was the immediate successor of Lake Newberry and had a broad relationship, covering the provinces of both the Seneca and Genesee basins and extended eastward to the neighborhood of Syracuse. The name is Lake Hall, after James Hall, whose district under the early survey of the State included the western end of the State and much of the territory covered by these waters.

4 Lake Hall received as tributary drainage all the glacial waters and the land streams of the central New York valleys as far east as the Onondaga valley, and probably as far as to the Limestone and Cazenovia valleys, or to the village of Jamesville. It formed a narrow stretch of east and west water but with southward prolongations extending up the several deep valleys [pl. 36].

5 During the life of Lake Hall the ice barrier in the Syracuse district was a dam somewhat higher than that on the Batavia meridian. Possibly there were oscillations with temporary flow in either direction. But certainly there came a time when the ice front receded at Syracuse so as to uncover passes below 900 feet altitude, and then the central New York waters (Lake Hall) found

steady eastward escape to the Mohawk-Hudson, which had been cleared of its ice barrier. The waters with eastward flow, and under 900 feet, are here named Lake Vanuxem, after Lardner Vanuxem, a coworker with Hall and whose district included the Syracuse region [pl. 37].

6 The outlet channels of the Vanuxem waters lie on the north-facing slopes west of Syracuse, on Howlet hill and at Split Rock, while the channels of continued flow lie across the ridges east of Syracuse [pl. 4].

7 Continued recession of the ice front in the Syracuse district finally lowered Lake Vanuxem until it was represented only by the shallow waters over the Seneca-Cayuga depression (the Montezuma marshes area) and a separate narrow lake in the Genesee valley [pl. 38]. The series of east-leading channels which head east and north of Leroy and extend to Phelps were made by the ice-border or proglacial drainage during the lowering and extinction of Lake Vanuxem.

8 During the life and extinguishment of Lake Vanuxem the Warren waters were excluded from central New York and confined to the Erie basin by the ice barrier north of Batavia.

Subsequent to the extinction of Lake Vanuxem, the length of time unknown, the ice front readvanced in the Syracuse district with a consequent redamming of the central New York waters. The result was the re-creation of Lake Vanuxem (in rising levels) and possibly the renewal of Lake Hall.

9 While Lake Vanuxem II (or perhaps a Lake Hall II) was in existence the ice front receded from the scarp north of Batavia and Lake Warren extended its domain into central New York. The reason for postulating a second Lake Vanuxem or even a second Lake Hall is the absence of great channels across the salient north of Batavia, which would surely occur if Lake Warren had found central New York an unoccupied basin. The lack of channels phenomena in the Oakfield district is explained by assuming an approximation of level between the Warren and the central New York waters, along with the probability of an area of stagnant ice in the locality where the waters met [pl. 39].

10 The Warren waters immersed the channel features produced by the extinction of the first Lake Vanuxem, and its records, specially of the lowering level (Lake Dana) are found northward of the Leroy-Victor-Phelps channel. The Warren water, at about 880 feet, endured in central New York long enough to produce some frag-

mentary but positive beaches, deltas and weak erosion planes [pl. 33]. Then it was itself extinguished by another waning of the ice barrier in the region of Syracuse.

11 The singular and apparently contradictory relation in altitude of the stream channels southwest of Syracuse may be explained by supposing that the Marcellus-Cedarvale valley was blocked by entrapped ice (probably drift-buried) during the time when the Vanuxem waters existed but that the subsequent melting of the ice opened the pass for sub-Warren flow at an altitude inferior to the Vanuxem outflow. The great channels and cataracts southwest and southeast of Syracuse with altitudes under the Warren plane received at least their final expression by its outflow and down draining.

12 The sub-Warren (or hyper-Iroquois) waters must have lowered somewhat spasmodically, that is, rapidly as new outlets were suddenly found and slowly as the longer-lived outlets were being excavated. Only one decided pause has been registered in discovered beaches, that of Lake Dana, 700 feet [pl. 40]. The only strong channel that can be correlated in altitude with the Dana plane is the Marcellus-Cedarvale channel. To make this effective requires the assumption that the ice barrier lay northeastward so as to leave the north and south Marcellus (Ninemile creek) valley open.

13 The well developed river channel leading east from Fairport to Lyons [pl. 3] apparently represents an episode of proglacial drainage distinct from that which produced the Victor-Phelps channel series. It is supposed that this northern channel was cut or at least given its present form by proglacial river flow during a sub-Dana or hyper-Iroquois stage. Apparently it is the lowest and latest channel cut by glacial stream flow in western New York, correlating with the low passes through Syracuse. The hypothetical lake which overflowed by the Fairport channel extended westward from the Rochester district, with altitude only 30 or 40 feet higher than its successor, Lake Iroquois. This lake is named Lake Dawson, after Dr George M. Dawson [pl. 41].

14 Niagara falls and Lake Erie came into existence while the falling hyper-Iroquois waters were recutting the lower channels, under 600 feet, at Syracuse, and later the channel leading east from Fairport, near Rochester. The emergence of the Niagara escarpment at Lockport and Lewiston above the lowering waters produced a barrier which confined the western waters to the Erie basin [*see* p. 30].

15 Succeeding the Dana and Dawson episodes the next long-permanent water level in the Ontario basin is that of Lake Iroquois. Its level was determined by the pass at Rome leading over to the Mohawk valley. About Syracuse the Iroquois shore-line features have an altitude of 430 to 440 feet; but are about 460 feet near Rome [pl. 42].

Conclusion. It does not seem possible that the history of the glacial waters in central New York can be any more simple than given in the above outline. On the contrary it is probable that future and more detailed study will discover new elements in the glacial history and find the series of events more complicated. It is therefore possible that some of the above theory may be wrong. However, there is no doubt of the existence of the several planes of glacial waters as discriminated above, nor of the production of the channels by ice border rivers. These facts of observation will stand even if the interpretation may change.

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New York State Museum

JOHN M. CLARKE, Director

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2 Botany
3 Economic Geology
4 Mineralogy
5 Entomology
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7 Economic Geology
8 Botany
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10 Economic Geology
11 "
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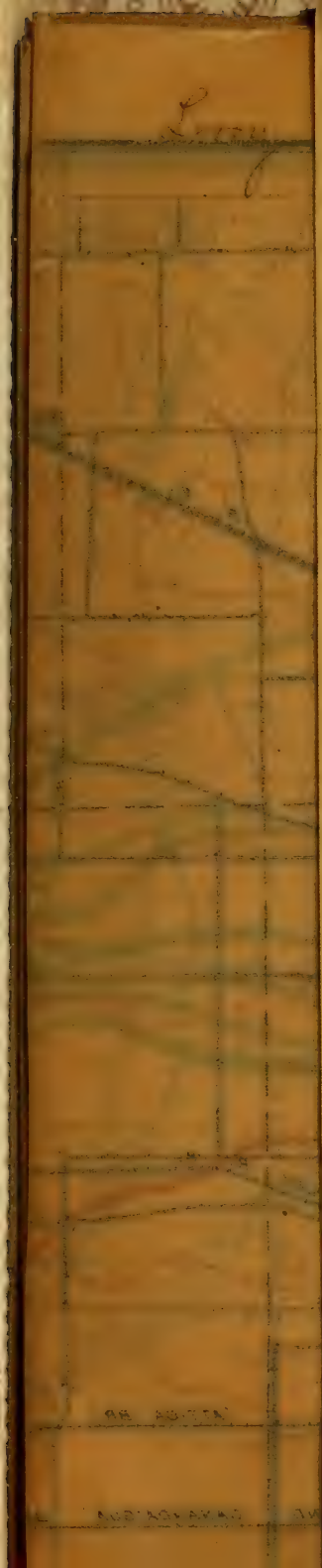

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